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UNIVERSITY COLLEGE OF WALES,
ABERYSTWYTH.

WELSH PLANT BREEDING STATION.

Trials with Pedigree Strains of Herbage Grasses.

PRICE 5/-.

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CONTENTS.

Page.

YIELD, PALATABILITY AND OTHER STUDIES ON STRAINS OF VARIOUS GRASS SPECIES. 1

(With Two Plates and Two Text-figures)

R. G. STAPLEDON AND W. E. J. MILTON.

Introduction 1
The Weather 10
Palatability 10
Hay and Aftermath 32
Pasture 40
Behaviour of the Sheep 74
Summary and Discussion 76
References 78
Explanation of Plates 79

THE INFLUENCE OF NITROGENOUS MANURES ON THE CHEMICAL COMPOSITION OF THE PRODUCE OF INDIVIDUAL GRASSES AS PASTURE, HAY AND AFTERMATH. 80

T. W. FAGAN.

VARIATIONS IN THE WEIGHT OF SHEEP: A NOTE AS TO PROCEDURE. 93

LL. IORWERTH JONES.

Page.

PRELIMINARY EXPERIMENT TO TEST THE REACTION OF SHEEP (LIVE WEIGHT INCREASE) TO DIFFERENT SPECIES AND STRAINS OF GRASSES AND CLOVERS AND TO TEST THE YIELD AND OTHER CHARACTERS OF THE SPECIES AS SUCH. 95

(With One Plate and Five Text-figures).

Ll. Iorwerth Jones.

Introduction 95
Material and Methods 95
Botanical Composition and Persistency 98
Yield of Herbage 103
Live Weight Increase of the Sheep 112
Carrying Capacity of the Pastures 115
Summary and Discussion 118
References 121
Explanation of Plate 121
Appendix

PLANT LIST.

PREFATORY NOTE.

The trials reported upon in this *Bulletin* represent the natural development of the work relative to the management and improvement of grassland in progress at the Station. The aim is to conduct a critical and comprehensive exploration of the factors influencing the behaviour of pastures in relation to the grazing animal and of the grazing animal in relation to pastures.

These investigations are being carried out along two main lines, namely (a) detailed physiological investigations on adult plants, seeds and seedlings, and (b) field experiments, an important feature of which is the technique which is employed with a view to facilitating the elucidation of special aspects of the problems involved.

The field trials fall into three main groups, namely (1) Those conducted on old established swards ; (2) Those carried out on plots sown with seeds mixtures, and (3) Those which deal with individual species and strains of herbage plants.

The results here under review are concerned wholly with pure-species plots and with very simple seeds mixtures, and derive their chief interest from the endeavour which has been made to give a quantitative estimate of the yield of pasture grass under conditions approximating very closely to those of ordinary farm practice : while perhaps of even greater significance are on the one hand the figures which give a fairly reliable quantitative picture of the relative palatability of a number of species and strains, and on the other the data relative to live weight increase and carrying capacity.

An important feature of these trials has also been the fact that they have rendered possible a critical comparison of the effect of repeated applications of inorganic nitrogen on the seasonal yield of species *qua* species and strain *qua* strain.

These particular experiments have created a large amount of interest just because of the novelty of the technique employed—and great surprise has been evinced at the manner in which sheep have been successfully used on plots no larger than 1/150th acre. It is not by any means claimed that the methods which will be described are not open to criticism and cannot be greatly improved upon. The methods are, however, of interest because in one series of experiments sheep have been folded in very small plots and in the other they have been tethered in pairs and kept to their particular plots by this means.

The point to be emphasised is that the evolution of a perfect technique for the elucidation of problems so diverse and so manifold as are those connected with grassland must of necessity be a very slow process. At this early stage in the movement towards the adoption of research methods in relation to grassland we must to an especially marked degree be prepared to judge our technique by the one and only standard that is applicable. Does it assist towards the better understanding of our problems ? And is it such as will lead to the evolution of ever more accurate and reliable methods ?

In my own view the time has not nearly approached when any effort should be made to attempt to standardise experimental methods as applied to grassland—neither (a) in so far as controlling the grazing animal is concerned ; (b) with reference to ecological methods of study ; (c) with reference to botanical analyses of herbage, nor (d) in any other respect. Rather is it desirable to encourage an unfettered exploration of all possible avenues of approach to this difficult and fundamental aspect of the grassland problem.

One thing is quite certain; critical grassland research entails an enormous number of painstaking, accurately conducted and time-taking operations. Thus the time sheets show that the sample cutting alone in connection with the trials described in the first article of this *Bulletin* over the four-year period was responsible for 857 men hours. While at a conservative estimate the botanical separations undertaken during the four years took not less than 5,208 technical assistant (young women) hours.

I need hardly add therefore that investigations such as this would be quite impossible without the heartiest co-operation of a comparatively large "non-commissioned" staff, and my thanks are due in a very special degree to Miss C. Jones, the senior technical assistant, and the whole of her staff, for the manner in which they have conducted their all-important share of the work. Thanks are no less due to Mr. Watkins, the Superintendent of the Farm and Gardens, and to the men responsible for the actual cutting of the samples. The services of the shepherd deserve a special word of recognition, for the proper handling of tethered sheep demands unremitting care and attention.

My thanks are due to Mr. William Davies, M.Sc., who was in general charge of the experiment with folded sheep in the first harvest year, and to Messrs. I. G. Lewis, N.D.A., now on the staff of the Research Station at Bingley, E. L. Jones, B.Sc., N.D.A. (Hons.), and J. O. Thomas, B.Sc., N.D.A., N.D.D., who, when students of the Agricultural Department, at various times and in various ways assisted Mr. Milton in the general conduct of this experiment. Mr. Martin Jones, M.Sc., now on the staff of the Jealott's Hill Agricultural Research Station, was responsible for setting up the experiment with tethered sheep, and I am indebted to him for assistance in the earlier conduct of the trial.

The fact that the trials have been supported by important chemical evidence is entirely due to the purposeful co-operation of Professor Fagan, to whom once more I am most profoundly indebted. I would wish also to express my thanks to Miss Rhoda Jones for having kindly seen the *Bulletin* through the press.

The various grasses and clovers and other plants are referred to by their English or common names throughout. In order to assist those not conversant with these common names, a complete list of genera and species is given at the end of the *Bulletin*.

R. G. STAPLEDON.

Agricultural Buildings,
Aberystwyth.
October, 1932.

YIELD, PALATABILITY AND OTHER STUDIES ON STRAINS OF VARIOUS GRASS SPECIES

BY

R. G. STAPLEDON, M.A., and W. E. J. MILTON, N.D.A.

(With Two Plates and Two Text-figures.)

INTRODUCTION.

The investigations here discussed were conducted wholly on pure-species plots. The aim of the experiments was two-fold, in the first place, to compare and contrast pedigree strains of grass species produced at the Station with those derived from the ordinary seed of commerce, and in the second place, to acquire information relative to a number of factors influencing the rational management of pastures.

The trials have been conducted in such a way as to give quantitative evidence relative to the various species and strains on the following matters :—(1) Their precise behaviour under the influence of repeated dressings of an inorganic nitrogenous manure ; (2) Yield under pasture conditions—when sheep have been the defoliating " machines " ; (3) Yield of hay and aftermath ; (4) The relation of " stem " to leaf in both hay and pasture grass ; (5) Relative persistency ; (6) Ability to maintain a pure sward and to resist volunteer invasion by unsown species ; (7) Relative palatability ; (8) Seasonal reaction.

The data under discussion have been derived from three distinct experiments, of which by far the most comprehensive was that laid down on the Penglais Field in 1926. From this experiment results for four harvest years (1927-1930) are available. A subsidiary trial was sown on the Cwm Field in 1927, which has yielded data for one harvest year (1928), and a further trial was set up on the Pond Field in 1928 from which the evidence of two years (1929-30) is at our disposal.

Material and Methods.

In the main the technique adopted in connection with the Penglais experiment has also been applied to the other experiments. This technique must be described in some detail—while only the modifications adopted on the other fields need be mentioned.

The Penglais Field Experiment : Soil, Aspect and Previous Cropping.

The field has a westerly aspect and is on a moderate slope. The soil is a stony loam, somewhat thin towards the top of the field and of good depth lower down —the field as a whole must be considered of good average fertility, and has produced excellent crops of oats—two crops of oats immediately preceding the present experiment. The stubble was ploughed in October, 1925, and the field thoroughly cleaned during that winter and the early spring. Superphosphate at the rate of three cwt. per acre was applied to the oat crop in 1925.

The Species and Strains under Test.

Nineteen species and strains were brought under trial, and concerning the pedigree and specially procured strains the following brief particulars may be given. In the case of each species, plots were also sown with the ordinary seed of commerce.

Perennial rye-grass: *Pedigree, Ba* 1412. The seed used was derived from a population made up mainly of three plants (all resulting from seed from the same inflorescence, open-pollinated in an old pasture in Pembrokeshire) vegetatively propagated together with their selected progeny plants obtained by selfing and intercrossing. To these were added in minute proportion four plants of approximately similar type from old pastures in North Wales and the Midlands. Generally rather prostrate, relatively broad leaved and persistent type.

Perennial rye-grass: *Pedigree, Ba* 1413. Mass selected plants from a population of single plants derived from the cleanings of wild white clover, and seed pooled together for seed production. Selected for density and high tillering capacity.

Perennial rye-grass: *Norwegian "Jædersk," Ba* 1353. A strain developed in the Jæren district of south-west Norway from indigenous material. The seed was obtained direct from Norway.

Italian rye-grass: *Pedigree, Bb* 162. Two plants obtained from a selected plant by open pollination were the basis of this strain. They were selfed, and selected plants from amongst their progeny were pooled to form the basis of the strain. Rather lighter green than ordinary Italian rye-grass and more leafy.

Cocksfoot: *Pedigree, Bc* 1640. This was a population built up by the isolation of a number of plants originally obtained from the cliffs of West Cornwall. The plants were predominantly "tussock" in character and very leafy. Essentially a pasture rather than a hay type.

Cocksfoot: *Pedigree, Bc* 1163. This population was built up from the original caging of five typical and very large tussock plants collected from a gorse brake at Westward Ho! North Devon. This line has been more extensively tested than any other produced at the Station, and has given rise to bulky and leafy plants of marked persistency which have shown to excellent advantage on soils hardly good enough for perennial rye-grass. Essentially a pasture type.

Cocksfoot: *New Zealand* (*Akaroa*); *Commercial, Bc* 1642. Obtained through commercial channels in this country. Single plant tests showed that the seed gave plants which had all the characteristics of genuine Akaroa cocksfoot.

Timothy: *Pedigree, Bd* 309. Strain based upon a single plant produced from seed collected near Aberystwyth. This plant was selfed and also increased vegetatively, and its propagants and selected progeny plants pooled for seed-production. Later flowering, less tall and more profusely tillering than ordinary commercial timothy, but rather less dense and longer leaved than Bd 310 below.

Timothy: *Pedigree, Bd* 310. Strain based upon four selected plants grown from seed collected in Dorset. All very similar in type and probably all from the same inflorescence. These were propagated vegetatively and were self-pollinated, and the seed production population was made up of the four plants themselves, together with 30 plants selected from amongst their progeny. Of the same general type as Bd 309, but leaves shorter and plants more dense due to more profuse tillering.

Timothy: *Norwegian* (*Grindstad*), *Bd* 305. A local (farmer's) strain from Norway. Of the usual commercial type but rather less tall. Not as dense as Bd 309.

Meadow Foxtail: *Pedigree, Bh* 284. Population built up from selected indigenous plants with long and abundant leafage, persistent and relatively free from rust. Plants flowering decidedly later than those produced from the ordinary Finnish seed of commerce.

Golden Oat Grass: *Commercial, Bs* 233. Only the commercial strain was included. This is not a species upon which breeding work is being undertaken at the Station.

Red Fescue: *Pedigree, Bl* 728. Twelve plants selected to type from a large population derived from various sources, but all indigenous. These plants were increased vegetatively and pooled for seed production. Definitely, but not very widely, creeping, leafy, rather dense and particularly wintergreen.

Red Fescue: *New Zealand* (*Chewing's*): *Commercial, Bl* 895. Seed obtained from ordinary commercial channels—the plants shown by spaced tests to be truly representative.

All the pedigree strains mentioned above were Station-bred. As a matter of fact, however, not one of them represents more than a preliminary "selection"—material which as such had been "grown-on" on a small scale simply with a view to providing seeds for the conduct of preliminary trials, in order to test the swarding behaviour of markedly contrasting plant populations. It should be added that nearly all the pedigree populations had been built up from plants obtained in Great Britain, so that broadly speaking the contrasts here made are between indigenous strains and ordinary commercial strains. Remembering that these trials were laid down in 1926, and that the Station only commenced operations in 1919, it is obvious that nothing in the nature of pure breeding pedigree material could have been available. Very different is the case of pedigree stocks now in the making, and which will be available for trial at no very distant date.

Date, Rate and Methods of Sowing.

The seeds were sown without a nurse crop on May 4th, 1926, under ideal conditions; germination and establishment were exceptionally satisfactory. Indeed these proved ultimately to be the most satisfactory pure plots achieved at the Station, and the average standard of achievement has been relatively high. The seed rate was based on the acquired experience of the Station and was adjusted for each strain on the "real value" basis in relation to its germination and purity. The basal rates were as follows (in lb. per acre) for each species, respectively: Italian rye-grass, 30 lb.; perennial rye-grass, 25 lb; cocksfoot, 25 lb; timothy, 15 lb.; red fescue, 20 lb.; golden oat grass, 20 lb.; meadow foxtail, 25 lb.

Size and Arrangement of Plots.

The plots were 1/200th acre with sown paths of one foot separating them and a broad path running through the middle and lower series of plots, and were set out in three series of duplicate plots (*i.e.* six plots for each strain). The three series were treated as follows: (1) The top series was used for a palatability trial in such a way that the grazing sheep had selective access to all the plots alike (the plots were not separated one from the other). Pasture yield data were also obtained from this series; (2) The middle series was used from the outset (1st harvest year) for ascertaining pasture yields. Palatability data were also obtained from this series. In this case every plot was made to constitute a separate fold by a system of hurdling (Gloucestershire sheep hurdles)*; (3) The lower series was precisely similiar to

*The height of the ordinary Gloucestershire hurdle is 2ft. 6in. This did not prove to be quite high enough and one strand of fencing wire was subsequently run round the folds at about 6 in. above the top of the hurdles. We now employ specially constructed hurdles, the top rail being 3ft. above ground level, and these adequately control the movements of the sheep.

the middle series, inasmuch as each plot was separately hurdled off. In this case, however, hay and aftermath were taken in the 1st harvest year—the plots being used for pasture yield data in subsequent years. The actual size of the plots was 1/150th acre, and not 1/200th acre, because each fold included its share of the sown path. The general outlay of the plots is indicated in Plate 1, fig. 1.

MANURING.

On March 24th, 1927 (1st harvest year), the whole area of the experiment received potash at the rate of 400 lb. Kainit (20 per cent. K_2O) per acre and phosphate at the rate of 223 lb. superphosphate (35 per cent. P_2O_5) per acre. No subsequent application of these manures was made. The duplicate plot on each series was used for the addition of nitrogenous fertilizers (supplementing the potash and phosphate). The arrangement of the plots was such that for any particular strain within a series the potash-phosphate plot and the potash-phosphate-nitrogen plot were directly one above the other (and in the middle and bottom series each of course was made—by hurdling—to constitute a separate fold). The first application of nitrogen was made on March 24th, 1927 (1st harvest year). Subsequent to this date additional dressings were applied after each grazing (approximately at 4—6-weekly intervals). In the 1st harvest year the nitrogen was applied partly in the form of sodium nitrate and partly in the form of ammonium sulphate, in the second and subsequent harvest years it was applied wholly as nitro-chalk. The average number of applications of nitrogen per annum during the four years of the experiment was 8. In the 1st harvest year on the bottom section (hay and aftermath) the same amount of nitrogen was applied to the plots as to the pasture section, but it was applied in four dressings. The amount of nitrogen (N) applied (lb. per acre) to the " nitrogen " plots in each of the years was as follows :—1927, 107; 1928, 112; 1929, 90; and 1930, 78.

In the first harvest year the nitrogen was only applied to the top two-thirds of each " nitrogen " plot as it was thought that owing to the slope of the ground there might be seepage to the " no-nitrogen " plot immediately below. As there was not the least evidence of this, in subsequent years the whole plot was dressed. It should here be remarked that as all the yield data were obtained by a system of quadrat sampling (to be explained hereafter) there was presumably no great harm to be done by only dressing two-thirds of the nitrogen plot (appropriately dressed *pro rata* of course) and only taking samples from the manured portion. As a matter of fact there was a certain amount of error introduced, inasmuch as it was perfectly obvious that as the season advanced the sheep through their urine had largely distributed the nitrogen over the whole plot. In consequence, the portion of the plots from which the samples were always taken had by that much been deprived of their full quota of nitrogen.

It will be noted that the amount of nitrogen applied per annum was heavy. This was advisedly done in order to ensure an abundance of available nitrogen throughout the season, as the aim was to test not only the full potentialities of nitrogen relative to gross yield per annum, but also its influence on seasonal productivity.

In the first harvest year the nitrogenous manures were not weighed out separately for each plot, but only for each section ; it soon became evident that it was desirable to weigh the manure separately for each plot and this was afterwards the procedure adopted.

METHOD OF DEFOLIATION : SHEEP TECHNIQUE.

During the seeding year the plots were lightly topped over with the mowing

machine in July. They were lightly grazed in November; they were carefully cut with the scythe early in February (1927) and the dead grass pulled off with rakes, and again lightly grazed at the end of the month. The hurdles were set up at the end of April, 1927, and the experiment proper was started on May 4th, when the first grazing took place. At each grazing the procedure was as follows. First of all the pre-grazing samples were taken (by the method to be described) from all the pasture plots. The samples having been taken, the sheep were introduced. On the top (the free-run palatability section) this simply amounted to giving an appropriate number of sheep access to that section as a whole. The average number of sheep so introduced on each occasion was 42 in the first harvest year, but at each grazing in the second and subsequent harvest years the number was increased to about 60.

On the middle section (where each plot constituted a separate fold) it was necessary to introduce one sheep into each fold (=plot). By judicious opening of the hurdles accompanied by a certain amount of lifting, and after a little practice both on the part of the men and the sheep this presented no difficulties and soon became a very ordinary matter of routine. On an average it took three men about half an hour to distribute the sheep over one section of folds (42 plots). According to the season and the amount of growth the sheep were allowed 18-24 hours grazing when on plots from which palatability data were required (*i.e.* on the free-run palatability section and on the middle folded section in the 1st harvest year). At the termination of this period, the plots were again sampled (=post-grazing samples). It was only on rare occasions that 24 hours' grazing adequately defoliated the plots. On the free-run section the flock was left to graze until the plots were eaten down to the desired level. On the folded section the sheep were similarly left, but as a particular plot became sufficiently grazed the sheep responsible would be moved into another fold where the " keep " was more excessive and where it would assist the sheep responsible for that plot. In no case was a " nitrogen " sheep turned in to assist a " no-nitrogen " sheep. The aim at all times was to graze all the plots to the same extent and not to graze too hard. Usually a period of from 42 to 72 hours completed the grazing. Directly after the removal of the sheep each plot was very carefully topped off with a scythe (by a very skilled man) and the droppings knocked about and spread as evenly as possible. After this the nitrogen plots received their incremental dressing. The plots were then left to grow away until the next sampling-grazing date when the whole process was repeated. Owing to the enormous amount of work entailed (sampling and subsequent botanical and chemical analyses) at the height of the season it was quite impossible to graze as often as could have been desired. To graze, that is to say, when the herbage was in a growth-stage that would be deemed at its best by a skilled sheep man. The shortest growing period during the first harvest year of the experiment was 15 days and the average was about 26 days. In subsequent harvest years when the growth was less vigorous and when the grazings were fewer in number the average period was about 30 days. It was a matter of some surprise to all of us concerned with the experiment, and to a large number of visitors, to find how well a sheep " held to its work "—and a sheep confined to a 1/150th acre plot is undoubtedly held to its work—grazed down a plot (of cocksfoot, for example) standing almost in a condition of hay.

On the whole, the sheep undoubtedly " entered into the spirit " of the part they were expected to play in an extraordinarily gratifying manner. They settled down each to its fold and seemed perfectly contented and indeed gave further support to the view often expressed that experimental animals seem almost " to

enjoy " their experiences and in any event become increasingly easy to manage in proportion as they " gain experience " in the routine to which they have to conform. A sheep, however, even when confined to a " field " of the diminutive size of 1/150th acre, finds scope to respond to at least one of its inherent predilections—it will tend to " camp " at the top of that " field." This was rendered apparent by the extra growth at the top, especially of the no-nitrogen plots at certain times of the year—as well as by nocturnal observations made on the sheep from time to time.

With regard to the palatability trials, by sampling before and after the grazing period an estimate was arrived at of the amount eaten on each plot during each period. This amount would of course depend in part upon the breed, size, and personal idiosyncrasies of the particular sheep folded on a particular plot. All that it was possible to do was to use the same flock throughout a season—and to distribute the sheep amongst the folds in a quite haphazard manner at each grazing. Thus on the basis of the average figures for the season as a whole the data for any particular plot would be unlikely to have been unduly influenced by the reaction of a sheep of a particular character. Any marked individuality on the part of some of the sheep would probably have been of less consequence on the free-grazing palatability area than on the folded plots. As a matter of fact the careful notes and observations that were taken as well as the data as a whole do not suggest that individuality in the sheep affected the results to any material extent. The flock used consisted of Kerry Hill with a few Kerry Hill—Suffolk crosses, represented by ewes of an average weight of about 150 lb.

It should be unnecessary to emphasise the fact that the sheep in these experiments were used simply to produce their normal effects on a sward by defoliation, treading and excretion, and as natural " machines " with which to ascertain the coefficient of palatability of the several strains.* The feeding value of the grass strains was not as such under consideration ; but it is interesting to remark that the reaction of the sheep to their diet none the less forced itself upon our notice. Thus it was early apparent that the condition of the droppings varied quite considerably on the different plots and especially at certain dates. Although this evidence is incidental to the main purpose of the experiments, it is of sufficient interest to be dealt with in the body of this report along with other observations concerning the sheep themselves.

Methods of Sampling and Drying.

The plots were sampled by cutting the produce from within ten quadrats on each.

In the first harvest year a wooden frame with an inside measurement of 6 in. × 6 in. was employed. In subsequent harvest years and in connection with the other experiments the frame was enlarged to an inside measurement of 1 square foot. The herbage within each quadrat was cut hard to ground level with sheep shears and carefully collected. The produce from all the quadrats (=bulk sample) was then put into a scrim bag or, if the yield was low, into a chip basket. The produce was air-dried for a considerable period—being turned at regular intervals. The yields in all cases are expressed in terms of air-dried fodder per 1/100th acre.

The hay and aftermath plots were sampled by cutting a single 1/500th quadrat

*This emphasis is in fact highly necessary, for it is significant of the attitude of mind not only of farmers themselves but of a number of agricultural scientists that to use sheep merely to ascertain their influence on the sward seemed to strike the majority of our visitors as a quite extraordinary procedure and one rather remote from any possible practical application.

(a large wooden frame being used for the purpose, an outside margin being cut away first), and by the ordinary system of quartering, the bulk was reduced to a suitable size for air-drying.

Reservations Relative to Yield Data.

The aim throughout was to obtain comparative results as between the various species and strains and as between with– and without–nitrogen. The yields arrived at by the methods employed cannot be regarded as absolute, but owing to the very large number of plots it was quite out of the question to introduce further time-taking refinements into the technique employed. Under the method adopted both the figures for pasture yields as such and the "amounts eaten" are somewhat too high. The actual technique employed assumes that the two-three days grazing plus the final cutting off with a scythe reduced the whole plot to the same condition as the areas sampled with sheep shears. Such would not, however, have been the case despite the utmost skill with which the plots were in fact scythed down. Ideally the plots should have been again sampled after the scything, and the weight thus obtained should have been subtracted from that given a month hence by the pre-grazing sampling. The weight so arrived at would be the absolute yield given by a month's growth.

Since this was not done it follows that the figures for "amounts eaten" obtained by subtracting the weight of the post-grazing samples from that of the pre-grazing are also represented by figures which are throughout too high. Thinking in terms of "absolutes," it is then to be realised that all the data presented are subject to an error of constitution. Thinking in terms of relatives, and particularly in view of the fact that the contrasting behaviours under study are very pronounced, this constitutional error ceases to be of any very profound significance.

In connection with grassland studies where it is absolutely essential to make innumerable comparisons between widely contrasting variables, if headway is to be made, it frequently becomes necessary to compromise where the absolute is concerned, and advisedly to employ a technique which is subject to a certain measure of constitutional error. The technique is good or bad, reliable or the reverse, according not so much as whether a constitutional defect is absent or present, as whether if present, it is known to be present, and whether the amount of defect advisedly accepted is justifiable in relation to the quality of the data that are called for to elucidate the particular problems under study.

From the point of view of technique it is of interest to add that the refinements above mentioned have always been introduced where accurate yields are as such the prime requirements. In order to do so, and having regard to the enormous amount of work entailed, it is necessary, however, greatly to reduce the number of comparisons that are to be made.*

Methods of Botanical Analysis.

In cases where the sample did not exceed an air-dry weight of about 1/3 lb., the whole was subjected to analysis; when the sample was appreciably larger it was reduced by quartering to the appropriate size. All the samples in each of the four harvest years were separated into the "pure sown strain" and into "unsown species," and in the 2nd, 3rd and 4th harvest years wild white clover was separated as such.

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*Manurial trials on different types of grassland involving only six plots at each centre are now, for example, being dealt with by the use of sheep as defoliators and by sampling on the basis above outlined.

The important result follows that all the data are presented in terms of " pure sown strain." Since only one species (other than unsown impurity) was present in the produce from a single plot, it was found that trained assistants could make wonderfully clean separations of " the sown " from " the unsown " in the case of all the species, even on material in the air-dried state. This separating is a matter of keen observation and practice, a number of characteristics which a trained botanist would not normally employ in identifying a leaf of a grass being of decisive diagnostic significance, characters such as the shape of the dried leaf, marks due to fungus attack and very subtle shades (browns and fading greens) of colouration.

In the first harvest year after the samples had been separated into " pure species " and " unsown species " the " pure species "* was further separated into " stem " (which separation included stem proper and the sheath of the leaf) and " leaf " (the blade or lamina of the leaf only) in accordance with the routine practice of the Station. In the second harvest year, " stem " and " leaf " separations were only carried out on a few selected strains.

Plant and Tiller Counts.

Plant and tiller counts were made *in situ* on the ground by taking 10 quadrats per plot, using the 6 in. x 6 in. frame.

Palatability Estimations.

The labour entailed rendered it impossible to obtain quantitative data relative to palatability (pre- and post-grazing sampling) after the 1st harvest year.

In subsequent years palatability was estimated by careful note-taking before and after each grazing, and was scored on a scale of 0 – 100. In this connection it is pertinent to remark that any investigator who has been long concerned with the accumulation of quantitative data relative to any particular grassland problem is peculiarly well qualified to make " eye " determinations, and it becomes legitimate to place very considerable reliance on the determinations so made.

General Notes.

The experiment in all its phases was supported by an elaborate system of general note-taking ; an important aspect of this being the notes taken relative to palatability in connection with the collecting of the quantitative palatability data.

The Data from the Several Harvest Years.

First Harvest Year. Hay and aftermath yields were obtained on the lower section. Yield and quantitative palatability data were obtained from the pasture plots on both the open-palatability section and from the folded plots. The produce from all the plots was subjected to stem and leaf analysis and plant and tiller counts were made on selected species.

Second Harvest Year. Pasture yield data were obtained from the middle and lower sections, and the produce from selected plots was subjected to stem and leaf analysis. The relative palatability was scored only. Plant and tiller counts were made on selected species.

Third Harvest Year. Pasture yield data were obtained from the middle and lower sections, but none of the plots were subjected to stem and leaf analysis. The relative palatability was scored only. Plant and tiller counts were made on selected species.

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*With the exception of Chewing's fescue, the stem and leaf separations being unduly arduous in the case of these fine-leaved fescues.

Fourth Harvest Year. Pasture yield data were only obtained from selected plots, and these were not subjected to stem and leaf analysis. Plant and tiller counts were made on selected species and strains only.

CWM FIELD.

The part of the field used for the experiment which was sown in 1927 represented a medium loam of rather poor fertility—the field having been neglected for a number of years. The area had been sown down to a red clover trial in 1924, and this was ploughed up in December, 1925 ; the area being subsequently fallowed and cleaned until the sowing date of the experiments in 1927. During the period 1924-26 the field had received lime at the rate of 2 tons per acre and basic slag at 6 cwt. per acre. Twenty-six species and strains contributed to the experiment ; the following species not included on Penglais were sown at the basal seed rates stated :—crested dogstail 15 lb ; Yorkshire fog 25 lb ; *Agrostis* spp. 30 lb ; and *Bromus arvensis* 30 lb. In this experiment all the species and strains were sown in conjunction with wild white clover at the rate of 2 lb. per acre.

The seeds were sown without a nurse crop on May 7th, 1927. Neither the " takes " nor the " establishments " were as good as on Penglais and the plots as a whole were not as satisfactory ; although some were excellent, others were too poor to give reliable data.

This experiment, like that on Penglais, consisted of a " folded " series and a free-run series. The plots were rectangular in shape and were 1/100th acre except for a few plots devoted to pedigree strains of which there was little seed available—these were 1/400th acre.

Six cwt. of basic slag to the acre were applied before sowing the seed—no potassic manure was used. The nitrogenous manure was in this case nitro-chalk ; 112 lb. of N being applied in the first and 22 lb. of N (a single early spring dressing) in the second harvest year.

Data were obtained from the plots as follows. Plots which had received incremental doses of nitrogen were compared with plots without nitrogen. Pasture yields were obtained by taking pre-grazing samples. Post-grazing samples were not taken, and palatability was estimated on the score basis. The proportion of unsown species and of wild white clover contributing to yield from the plots was ascertained by the estimation method now largely adopted at the Station.* Plant counts and estimates were made.†

POND FIELD.

The part of the field used for this experiment which was sown in 1928 consisted of a rather poor, medium, stony loam, with a tendency to be heavier and wetter towards the bottom third of the area. The field had been under oats in 1927 and was thoroughly cleaned in the early spring of 1928.

Forty-nine species and strains were included in this experiment, the chief additions to those previously tested in Penglais and Cwm Field with their basal seed rates being :—tall fescue 30 lb ; meadow fescue 30 lb ; rough-stalked meadow grass 15 lb ; and sweet vernal grass 25 lb.

The seeds were sown without a nurse crop on May 10th, 1928. The conditions for " take " and establishment did not prove favourable and a number of the smaller species did not give rise to plots of sufficient merit to permit of the collection of

*See Davies and Thomas (1928), and Davies (1932).

†These plots were also critically examined in their seeding year and provided the material for an independent investigation. See Davies and Thomas, *loc. cit.*

data. Taking the plots as a whole, however, the experiment has given valuable evidence confirmatory of that obtained from Penglais.

All the pasture plots were folded, this experiment not including a free-run palatability series. A hay and aftermath section was, however, added. The plots were 1/200th of an acre and rectangular, and as before included a nitrogen and a no-nitrogen series.

Five cwt. of basic slag were applied prior to sowing the seeds, and in this case the initial dressing was supplemented in the first harvest year by a spring dressing of superphosphate at the rate of 2 cwt. per acre supported by $4\frac{1}{2}$ cwt. of Kainit. The nitrogen (incremental dressings) took the form of nitro-chalk—90 lb. of N being applied in the first and 56 lb. of N (dressings suspended during the mid-season grazings) in the second harvest year.

Data were obtained from the species and strains which gave rise to reliable plots as follows :—comparisons between nitrogen and no-nitrogen were made on pasture and on hay and aftermath plots. The pasture yields were obtained by taking pre-grazing samples. Post-grazing samples (for quantitative palatability data) were taken on selected species and strains. The contribution of unsown species and wild white clover was again ascertained by the adoption of the estimation plan. At the conclusion of the experiment in the second harvest year plant, tiller and wild white clover counts were made on lifted turfs.

THE WEATHER.

The chief features of the weather obtaining during the period of the experiments are set out in the accompanying statement.

It will be noted that the rainfall exceeded 40 inches in each of the years under consideration. Both 1927 and 1928 were, however, decidedly wetter than either 1929 or 1930 and particularly in so far as the early spring was concerned.

Relative to 1927, 1928, and 1930, the year 1929 must be regarded as a dry year—January to April were particularly dry months—while July was also drier than in the other three years. November and December were, however, abnormally wet in 1929. The relative dryness of 1929 was further accentuated by the fact that many more hours of sunshine were experienced during this year than in the other three. There was less sunshine in 1930 than in 1927 or 1928, although the rainfall was higher in the latter years.

The mid-temperatures do not show any very significant differences between the different years. January and February of 1929 were, however, relatively cold months.

PALATABILITY.

Before considering the large amount of evidence in detail in respect of strains in relation to each other and to the various treatments it will be convenient to look at the data from the point of view of wider and somewhat more generalized issues.

The Coefficient of Palatability of the Species as such for the Grazing Season as a whole.

The average results for the species have been brought together in Table I which gives the percentage eaten of the amount offering (coefficient of palatability) during an average grazing period of 24 hours. The outstanding result is the remarkably high palatability of timothy which on the average is slightly more palatable to sheep than even Italian rye-grass. No less striking is the very low palatability of the red fescue.

The accurate quantitative data from the first harvest year for Penglais Field and for Pond Field are in substantial agreement, for these three species and the

SUMMARY OF GENERAL METEOROLOGICAL CONDITIONS AT ABERYSTWYTH, 1927-1930.

		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Rainfall April–Oct. inclusive.
1927.	Rainfall in inches ..	4.4	3.3	3.6	2.1	2.0	5.8	6.0	6.4	6.0	3.8	3.7	2.8	49.9	32.1
	Sunshine in hours ..	38.7	82.6	92.7	146.7	219.9	172.2	122.0	156.0	106.7	114.5	75.9	33.3	1361.2	
	Mid-temperature. ..	41.3	40.2	44.3	44.5	51.7	52.7	58.8	58.0	53.8	51.7	44.0	36.3	—	
1928.	Rainfall in inches ..	7.4	3.8	2.0	1.1	0.7	5.6	3.9	6.7	2.1	6.6	7.0	4.2	51.1	26.7
	Sunshine in hours ..	51.3	76.9	103.2	147.4	195.1	162.6	197.4	172.8	183.2	112.5	63.0	36.6	1502.0	
	Mid-temperature. ..	42.1	43.5	42.5	46.6	51.8	53.9	57.3	58.0	54.6	50.8	46.6	39.9	—	
1929.	Rainfall in inches. ..	1.0	1.0	0.8	0.9	3.0	3.9	2.9	3.9	2.3	7.7	9.7	7.6	44.7	24.6
	Sunshine in hours. ..	86.0	69.2	248.6	177.6	240.8	235.7	198.5	151.6	173.4	91.6	48.3	53.1	1774.4	
	Mid-temperature ..	36.5	35.1	44.8	43.7	51.3	53.1	58.1	58.3	58.4	49.1	46.0	42.4	—	
1930.	Rainfall in inches. ..	5.7	0.4	2.5	1.7	2.5	2.4	4.2	4.7	4.6	6.5	5.0	6.8	47.0	26.6
	Sunshine in hours. ..	58.8	112.9	100.1	143.4	135.3	24.0	124.1	133.3	122.2	86.2	56.7	34.7	1131.7	
	Mid-temperature. ..	41.9	36.6	41.3	45.6	49.0	56.8	58.3	58.0	56.9	51.3	44.6	41.8	—	

figures as a whole leave no doubt as to their positions. It is interesting to find that on the average and under controlled methods of grazing cocksfoot is quite as palatable to sheep as is perennial rye-grass, and rather surprising to find that meadow foxtail and golden oat grass on the basis of the figures for the year round rank at least equally with the two former species, and it will be noted that they do so even on Penglais Field (where the average figures include the free-run area).

The notes entirely bear out the relatively high palatability of tall fescue—a result which was not to have been expected on the basis of previous trials reported from the Station†. The only data for this species in connection with the present

TABLE I.—*To show the average coefficient of palatability for the whole grazing season (percentage eaten of amount offering) in grazing periods of 24 hours for* 11 *species of grasses. Data from three fields based on average results of all plots (nitrogen and control; free-run and folded sections) and of all strains for each species.*

Species.	Penglais Field.			Pond Field.		Cwm Field.	Average for the species included on Penglais.
	First year. I.	Second year. II.*	Third year. III.*	First year. IV.	Second year. V.	First year. VI.	VII.
Timothy	48	93	93	55	52	73	69
Italian rye-grass..	45	94	—	49	65	81	67
Perennial rye-grass	34	69	60	41	52	64	53
Cocksfoot ..	37	64	67	43	58	70	56
Meadow foxtail ..	38	68	71	46	58	74	59
Golden oat grass	40	63	56	—	—	67	56
Red fescue ..	19	20	22	27	—†	—†	22
Meadow fescue ..	—	—	—	43	60	—	—
Tall fescue ..	—	—	—	36	60	—	—
Crested dogstail	—	—	—	—‡	61	62	—
Yorkshire fog ..	—	—	—	27	77	54	—

Notes:

I. Based on quantitative data free-run and folded sections.
II. Scored on a scale of marks free-run section only.
III. Scored on a scale of marks free-run section only.
IV. Based on quantitative data folded section only.
V. Scored on a scale of marks folded section only.
VI. Scored on a scale of marks folded section only.
VII. Average figures are based on data from all the fields.

* On no plots and in no year were the yields as high as on Penglais in the first harvest year, and thus, of course, the coefficients were higher on that field in the second and third years than in the first.

† Plots containing excess of wild white clover making it impossible to score the palatability of the grass species as such.

‡ Not sufficiently good plot to obtain reliable samples.

experiment were, however, obtained on folded plots—under these conditions meadow fescue is also decidedly palatable. The point is that tall fescue may be palatable when it is itself abundant on areas where the herbage as a whole is scant, and this is the case on many of the swards where tall fescue normally occurs.

†See Davies (1925).

Yorkshire fog is low in the scale of all-the-year-round palatability. The high figure in the second harvest year on Pond Field is interesting, but the plots were then rather poor and not high yielding ; this grass, furthermore, was not nearly as stemmy in the second as in the first harvest year. Crested dogstail would seem to rank about level with perennial rye-grass in its all-the-year-round scale of palatability.

The coefficient of palatability was estimated on the score basis after a further average period of 24 hours (*i.e.* after a total period of 48 hours) in connection with most of the trials. Results are available for both free-run and folded areas. It is not necessary to give the results in detail. By the end of 48 hours up to 97 per cent. of the timothy offering on some of the plots had been eaten, while despite the generally higher yield of Italian rye-grass not infrequently 95 to 96 per cent. of this species had been converted.

At the end of 48 hours perennial rye-grass, cocksfoot and meadow foxtail, although decidedly less palatable than Italian rye-grass and timothy when judged by the 24 hour criterion, were but little less well eaten, most of the plots showing coefficients of 90 to 96 per cent. At the end of the 48-hour grazing period, the less palatable of two strains within a species of fairly high palatability also tends very closely to approach the more palatable. Thus indigenous cocksfoot with a coefficient of palatability of 54 per cent. (average of two experiments) at the end of 24 hours had reached an average of 88 per cent. in 48 hours—the comparable figures for commercial cocksfoot being 78 per cent. and 92 per cent.

The species of definitely low palatability, however, showed to considerable disadvantage even when estimated after a 48-hour grazing period. Thus the figures for red fescue varied from 73 per cent. to never higher than 86 per cent. and for Yorkshire fog from 75 per cent. to 81 per cent.

The Amount Eaten During an Average Period of 24 hours for the Species as such for the Grazing Season as a whole.

The coefficient of palatability is an excellent guide to the relative palatability of the species when there is a sufficient amount of keep offering on all the plots and when the amount is also not excessive. The coefficient is, however, a function not only of the sheep's preference or liking for the species, but also of the actual amount offering to the sheep. For no matter how palatable a species, a sheep can only make a certain impression on a given plot in a given period of time. The grazing period employed (*i.e.* 24 hours) in relation to the size of the plots used (1/150th acre) has undoubtedly given reliable and generally comparable coefficients, but it is also of considerable interest to compare the species from the point of view of the "amount eaten" (in 24 hours). It is "amount eaten" per unit of time which probably gives the surest indication of the value of a species as a herbage plant.* The available data are brought together in Table II.

The results from Penglais and Pond Field cannot be directly compared, for on the former field the plots were larger than on the latter, while the yields (amount offering) were also higher on Penglais, and thus the actual "amounts eaten" per 24 hours were much greater on this field. Italian rye-grass yielded well on both fields, and being highly palatable on the average of both trials gives the greatest "amount eaten." Timothy on Pond Field gave nearly as good yields as most other species and thus by virtue of its high palatability value was second only to Italian rye-grass in "amount eaten." The yields of these two palatable species were much

*It is to be remembered that the figures given for "amount eaten" are to be regarded not as absolutes, but only as relatives as between the different species and strains (see page 7).

TABLE II.—*To show the average "amount eaten"* during the grazing season as a whole (in grazing periods of about 24 hours) in the first harvest year respectively on Penglais Field and on Pond Field for 9 species of grasses. Weights in lb. of air-dry fodder from plots of 1/150th acre on Penglais and 1/200th acre on Pond Field. The figures are the average of the nitrogen and control plots. On Penglais the free-run and folded plots contribute to the average. On Pond Field data from folded plots only are available.*

Species.	Penglais Field.	Pond Field.
Timothy	19.9	13.3
Italian rye-grass	24.7	15.5
Perennial rye-grass	20.7	10.5
Cocksfoot	23.5	10.2
Meadow foxtail	21.5	8.5
Golden oat grass	24.9	—
Red fescue	14.9	4.3
Meadow fescue	—	11.3
Yorkshire fog	—	7.3

*See note on previous page.

lower than those of the other larger grasses on Penglais, but so palatable is timothy that even so the amount actually eaten was nearly as great as in the case of perennial rye-grass (the yields being 40 per cent. in favour of the rye-grass). Golden oat grass (relatively high yielding) actually gives an "amount eaten" figure as high as that of Italian rye-grass. The low palatability of red fescue is brought into strong relief by the "amount eaten" figures. On Penglais the indigenous red fescue (first harvest year) was actually fourth in the scale of yield, but yet it was eaten to a relatively slight extent compared to the more palatable grasses, and this was as true of the folded as of the free-run plots. On Pond Field the red fescue yielded practically as well as the meadow foxtail, for example, but twice as much foxtail as fescue was actually eaten during the year. Yorkshire fog on Pond Field gave yields quite as high as those of perennial rye-grass and cocksfoot, but the "amount eaten" was considerably less.

The Influence of Nitrogen for the Average of all the Grazings on the Species considered as a whole.

Average data from all the species under test (considered as one unit) are brought together in Table III. When considering the evidence it must be realized that on the average nitrogen has occasioned an increase in yield of about 50 per cent. over and above that of the control plots. It follows that for the nitrogen plots to show an increased coefficient of palatability the sheep would have to graze with an exaggerated partiality on the free-run area, and to eat an enormous quantity of fodder on the nitrogen plots in the folded series.

The exact quantitative evidence from Penglais (first harvest year) does suggest a decided partiality for the nitrogen plots on the free-run area, the coefficient of palatability being 5 per cent. higher (on the average for all the species and for all the grazings) than on the control plots. The coefficient is also slightly higher on the nitrogen plots in the second harvest year. In the third harvest year the advantage, however, is slightly in favour of the control plots. In all probability this is largely to be accounted for by the altogether greater spread of volunteer

TABLE III.—*To show the effect of nitrogen on* (1) *the coefficient of palatability* (*percentage eaten of amount offering*) *and* (2) *the "amount eaten" during the whole grazing season* (*in grazing periods of 24 hours*) *for the average of all the grass species under test.*

Field and harvest year.	Nitrogen.		Control.	
	Free-run.	Folded.	Free-run.	Folded.
Coefficient of palatability (percentage eaten of amount offering).				
Penglais : 1st harvest year (a)	40	39	35	41
Pond Field : 1st harvest year (a)	—	41	—	42
Penglais : 2nd harvest year (b)	68	—	66	—
Penglais : 3rd harvest year (b)	54	—	57	—
Cwm Field : 1st harvest year (b)	—	62	—	65
"Amount eaten" in lb. per plot of air-dry fodder.				
Penglais : 1st harvest year (a)	22.2	28.6	15.8	19.8
Pond Field : 1st harvest year (a)	—	11.4	—	7.6

Notes : (a) Quantitative data. Penglais plots 1/150th acre ; Pond Field, 1/200th acre.
(b) Based on scores.

wild white clover on the control than on the nitrogen plots—a counterbalancing effect which had begun to be operative even in the second harvest year.*

On the folded sections the coefficient of palatability, as would be expected, is higher on the control plots. The fact that the difference between "nitrogen" and "control" is no greater than it is, and is only slightly in favour of the former, is in itself (having regard to the higher yields from the nitrogen plots) evidence of the greater average palatability of the nitrogenized herbage.

The figures for "amount eaten" on both fields and under both methods of grazing show to the marked advantage of the nitrogen plots. Thus on the free-run section where the sheep were able to choose their plots (species and strain ; nitrogen or control) they ate 41 per cent. more from the nitrogen than from the control plots. On the folded section where they were confined to a particular species and strain and to a particular treatment (nitrogen or control) they ate 44 per cent. more on the nitrogen plots than on the control on Penglais and 50 per cent. more on Pond Field.

These figures undoubtedly indicate a really remarkable preference on the part of the sheep for nitrogenized herbage ; for they are based on a grazing period of only 24 hours—a period over which the control plots were offering an ample sufficiency of keep, and from which, in practically all cases, the sheep could have taken as much as they actually took from the nitrogen plots. This is well seen in the case of some of the higher yielding species where the keep was excessive even on the control plots. Thus on the average of all the cocksfoot plots throughout the season the amount eaten was 50 per cent. in favour of nitrogen on the free-run section and 25 per cent. on the folded section.

*It must be remembered that the figures in the table are based on the results given by the pure grass species. Evidence will be discussed later which, however, suggests that the presence of wild white clover tends to add to the palatability of the grasses.

Stem and Leaf Relationships for the Species as a whole and for Characteristic Species as such.

On the average of all the species and of the free-run and folded sections (Penglais Field first harvest year) the sheep ate 43 per cent. of the leaf offering and only 27 per cent. of the stem offering. The influence of nitrogen in this respect was negligible, except that on the folded section the evidence suggests that a rather higher proportion of stem (6 per cent. to be precise) was eaten on the " nitrogen " plots.

With regard to the actual amount of leaf and of stem eaten on the average of all the species for both methods of grazing, the amount of leaf was nearly four times as much as that of stem. The weight of stem removed from the folded plots receiving nitrogen was nearly twice as great as that from either of the controls or from the free-run " nitrogen " plots. This result is in complete confirmation of the records taken while the sheep were grazing. It was noted that on the nitrogen plots of the folded sections the sheep tended to concentrate *seriatim* on particular spots and that they grazed these practically to ground level before turning their attention to other parts of the plot. This type of selective grazing was not in marked evidence on the free-run area and was only observed to take place to a slight extent on the control plots of the folded area.

The species varied in an interesting manner as to the proportion of leaf and stem actually eaten. The state of affairs is well shown by the figures hereunder which are the average of all plots (nitrogen and control; free-run and folded sections, Penglais first harvest year).*

	Percentage contribution of leaf and of stem to the ration actually eaten. The figures in brackets are the percentage of leaf in the herbage offering.	
	Leaf.	*Stem.*
Average of all species and strains ..	79 (71)	21
Indigenous red fescue	93 (86)	7
Meadow foxtail	89 (85)	11
Italian rye-grass	72 (66)	28
Golden oat grass	52 (56)	48

It is thus seen that in the ration taken by the sheep golden oat grass occupies a unique position with nearly as much stem as leaf eaten. Italian rye-grass also offers a high proportion of edible stem readily eaten by sheep.

At the other extreme we have red fescue and meadow foxtail, species of which an unusually small amount of stem is eaten. Species like perennial rye-grass, timothy and cocksfoot occupy a normal position with usually about 20 per cent. stem contributing to the ration selected by the sheep.

The considerable amount of stem taken in the case of golden oat grass and Italian rye-grass is undoubtedly due not only to the stemmy nature of their herbage, as such, but also in large measure to the exceptionally erect manner of growth of these species, which renders the stem (including sheath in the classification adopted) unusually accessible. While the small amount of stem taken from meadow foxtail and red fescue, although largely due to the very high proportion of leaf in the herbage of these species, is probably also in considerable measure due to the

*It should be particularly noted that the figures in the statement include the folded and the free-run sections. In a subsequent section dealing in more detail with stem and leaf (see p. 20), for reasons which are there explained, only the free-run section is taken into account.

close growth of the fescue and to the spreading nature of the leafage of the meadow foxtail.

Nitrogen has no very marked differential influence on species *qua* species as affecting the stem : leaf ration, except that in the case of golden oat grass a rather higher proportion of stem appears to be eaten on the nitrogen- than on the control plots, high as is the proportion even on the latter plots. These results it must be remembered have been based on the average of the free-run and folded sections.

THE BEHAVIOUR OF SPECIES AND STRAINS CONSIDERED IN DETAIL.

In presenting the results for the various species and strains it is unnecessary to give the data separately for the free-run and folded sections in the cases where such data are available. It is an interesting and rather remarkable fact that palatability data collected respectively on the free-run and folded basis are decidedly confirmatory, both sets of data, with but few exceptions, placing the species and strains in substantially the same order. It follows that a ewe tends to display the same degree of relish for a particular strain or a particular species no matter whether she is folded on that species or strain or whether she is able to graze selectively from amongst a number of plots.

The statement hereunder for the average of the different species (Penglais Field first harvest year) shows how close is the general agreement between the data from the free-run and folded sections.

	Coefficient of palatability.			
	Free-run.		*Folded.*	
	Nitrogen.	*Control.*	*Nitrogen.*	*Control.*
Perennial rye grass	36	30	33	36
Italian rye grass	48	44	49	40
Cocksfoot	38	32	38	40
Timothy	50	49	45	49
Meadow foxtail	40	30	42	37
Golden oat grass	41	27	43	48
Red fescue	18	16	12	24

Data for comparing the several strains of the different species are set out in Tables IV and V—the tables are self-explanatory.

The figures for coefficient of palatability (Table IV) reveal a few interesting differences between the various strains of one and the same species.

The indigenous strains of perennial rye-grass would appear to be quite as palatable as the ordinary commercial. There is at least an indication that indigenous strain No. 1412 was somewhat more palatable than No. 1413, although both strains represented the prostrate pasture type of growth. The Norwegian " Jædersk" strain was on the average quite as palatable as other strains (although the figures do more than justice to it as the amount offering was less than on the other plots), and indeed in the second and third harvest years showed to good advantage. This strain contained a number of plants which were badly rusted and burned, but by the second harvest year a large proportion of these had died out with the result that the plot as a whole presented a decidedly more palatable herbage than in the first year.

The data for cocksfoot go to confirm the general impression that the indigenous strains are not as palatable as the ordinary Danish commercial, and show further that they are not as palatable as New Zealand cocksfoot. The average figures are,

however, somewhat biased in favour of the commercial strain, inasmuch as the amount offering on the plots representing this strain was less in the second and third harvest years than on the plots representing the indigenous strains. The notes taken during the grazing periods tend, however, to confirm the trend of the figures and there can be no doubt that the indigenous strains under test were not as acceptable to the sheep as were the commercial. This preference for the commercial strain was not nearly so pronounced at the end of a 48-hour grazing period though even then the indigenous strains were still at a slight disadvantage. The average figures for the three fields (at the end of 48 hours) show a coefficient of palatability for the commercial strain of 93 per cent. and for the indigenous strain of 88 per cent.

There can be little doubt that the preference for the commercial strains is very largely due to accessibility—consequent upon their more erect habit of growth; an advantage that ceases to be operative after selective grazing has been continued for a considerable period.* Here again there is a suggestion of differential palatability as between indigenous strains of very similar growth form—No. 1163 showing slightly higher palatability than No. 1640.

The indigenous strains of timothy would appear to be quite as palatable as the commercial. It is interesting to find that the indigenous strain No. 310, although of rather denser growth than No. 309, yet shows a somewhat higher palatability. It is, however, to be remarked that the plots of the latter strain contained rather more volunteer bent than those of the former, and this may possibly not have been without influence on the result. This difference in palatability taken in conjunction with the behaviour of indigenous strains of rye-grass and cocksfoot perhaps suggests that strains vary amongst themselves in inherent palatability.

The plots of commercial meadow foxtail were so poor and so rusted that no reliable data could be obtained from them—all the indications were, however, that even the greenest leafage from these plots was no more, if as, palatable to sheep as the average leafage from the indigenous plots.

The small amount of data available for meadow fescue suggests that the ordinary commercial strain was slightly more palatable than the pedigree strain from Sweden, and this probably on the score of accessibility. The indigenous was the only strain of the red fescues that gave good enough plots for reliable data, the plots, however, indicating that there was little difference in palatability between this strain and Chewing's fescue.

As before explained, the effect of nitrogen on the coefficient of palatability is largely masked by the increased yields on the nitrogen plots. There is, however, at least an indication that nitrogen actually increases the coefficient of palatability in the case of Italian rye-grass and Yorkshire fog. With regard to the various strains within the species there is no evidence of any marked differential influence.

As before shown, it is in respect of " amount eaten " that nitrogen shows to such good effect. Thus in the case of the more reliable data from Penglais Field (see Table V), with the single exception of indigenous red fescue every strain under test has given a decidedly higher figure for " amount eaten " on the nitrogen than on the control plots. The indigenous meadow foxtail and the Jædersk rye-grass show increases in favour of nitrogen of as much as 40 per cent., and this despite the fact that the yield on the control plots of both strains was decidedly high. The Pond Field data agree with those of Penglais in that most of the strains have shown

*The palatability of cocksfoot is influenced to a marked extent by the degree of scabrosity of the leaf margins (see Christoph (1925)). The indigenous strains here under test were not, however, more scabrous than the commercial. Endeavour is now being made to breed strains with the minimum of scabrosity.

TABLE IV.—*To show the coefficient of palatability (percentage eaten of amount offering) for the whole grazing season based on the average of all the grazings (average grazing period 24 hours) for the various strains of the different species separately. Data are given for the nitrogen and the control plots.*

Species and strains.	Nitrogen.							Control.						
	Penglais.			Pond Field.		Cwm Field.	Average.	Penglais.			Pond Field		Cwm Field.	Average.
	First year.	Second year.	Third year.	First year.	Second year.	First year.		First year.	Second year.	Third. year.	First year.	Second year.	First year.	
Perennial rye-grass : *ex* wild white ..	—	—	—	—	—	51	—	—	—	—	—	—	49	—
Indigenous 1412	36	64	65	—	—	—	55	38	71	58	—	—	—	55
,, 1413	33	65	60	—	—	—	53	35	62	44	—	—	—	47
,, 1752	—	—	—	43	45	—	—	—	—	—	24	44	—	—
Jaedersk ..	33	78	68	—	—	—	59	30	79	66	—	—	—	56
New Zealand ..	—	—	—	—	41	58	—	—	—	—	—	45	64	—
Commercial ..	35	67	58	49	53	—	52	28	65	60	50	63	—	53
Italian rye-grass : Pedigree ..	45	95	—	—	—	—	70	37	95	—	—	—	—	66
Commercial ..	53	93	—	53	71	81	70	46	92	—	46	65	78	65
Cocksfoot : Indigenous 1640 ..	34	54	46	—	—	—	45	26	53	43	—	—	—	41
,, 1163 ..	39	43	47	36	67	55	49	37	49	50	46	60	61	51
New Zealand ..	35	75	81	—	64	71	65	38	71	87	—	77	71	69
Commercial ..	45	78	92	47	66	81	68	44	82	93	41	66	66	65
Timothy : Indigenous 309 ..	43	92	88	—	—	71	74	43	98	96	—	—	68	76
,, 310 ..	51	95	96	—	—	—	81	51	98	96	—	—	—	82
,, 352 ..	—	—	—	55	48	—	—	—	—	—	54	51	—	—
Grinstad ..	52	82	86	—	—	—	73	56	86	94	—	—	—	78
Commercial ..	43	94	96	46	51	72	67	45	97	91	62	58	71	70
Meadow foxtail : Indigenous ..	41	66	55	44	52	65	54	34	66	71	42	63	76	59
Golden oat grass : Commercial ..	42	69	53	—	—	57	55	37	57	58	—	—	77	57
Red fescue : Indigenous ..	15	22	23	20	—	—	20	20	16	22	36	—	—	23
Meadow fescue : Swedish ..	—	—	—	38	62	—	—	—	—	—	56	52	—	—
Commercial ..	—	—	—	40	58	—	—	—	—	—	37	63	—	—
Tall fescue : Commercial ..	—	—	—	35	57	—	—	—	—	—	37	59	—	—
Yorkshire fog ..	—	—	—	31	74	58	—	—	—	—	22	80	50	—

NOTES.—Penglais first harvest year and Cwm Field first harvest year average of free-run and folded areas.
Penglais second and third harvest years free-run area only.
Pond Field first and second harvest years folded area only.
Penglais first harvest year and Pond Field first harvest year on basis of quantitative data.
Other figures on basis of scores.

TABLE V.—*To show the amount eaten (in lb. air-dry fodder per plot) in average grazing periods of 24 hours for the whole grazing season for the various strains of the several species separately. Data are given for the nitrogen and the control plots.*

Species and strains.	Penglais Field.* First harvest year.		Pond Field.† First harvest year.	
	Nitrogen.	Control.	Nitrogen.	Control.
Perennial rye-grass : Indigenous 1412 ..	29	23	—	—
,, 1413 ..	25	17	—	—
,, 1752 ..	—	—	12	4
Jædersk	17	10	—	—
Commercial	23	16	15	11
Italian rye-grass : Pedigree	29	17	—	—
Commercial	31	21	18	13
Cocksfoot : Indigenous 1640	23	15	—	—
,, 1163	27	21	8	8
New Zealand	25	19	—	—
Commercial	35	25	16	9
Timothy : Indigenous 309	23	17	—	—
,, 310	28	20	—	—
,, 352	—	—	19	10
Grinstad	23	17	—	—
Commercial	17	13	13	10
Meadow foxtail : Indigenous	34	20	11	7
Golden oat grass (Commercial)	30	19	—	—
Red fescue : Indigenous	14	15	4	4
Meadow fescue : Swedish	—	—	11	8
Tall fescue : Commercial	—	—	10	5
Yorkshire fog : Commercial	—	—	9	6

Notes : *Average of free-run and folded areas.
†Folded plots only.
Penglais per 1/150th acre plots.
Pond Field per 1/200th acre plots.

to the marked advantage of nitrogen, but again red fescue has been eaten no better than on the control plots. The commercial cocksfoot has given a higher increase in " amount eaten " due to nitrogen than have the indigenous strains of this species, indeed, taking the data as a whole no strain has given a greater bulk of herbage acceptable to sheep in the first harvest year. The figures for meadow foxtail, golden oat grass and Italian rye-grass are also very high under nitrogen. The high standard of palatability of the indigenous strains of perennial rye-grass and timothy is further shown by the fact that it has been these strains and not the commercial which have given the highest figures for " amount eaten," and this both on the nitrogen and control plots—and in the first harvest year.

THE BEHAVIOUR OF THE SPECIES AND STRAINS IN RESPECT OF STEM AND LEAF.

Owing to the peculiar manner, which has been previously referred to, in which the sheep grazed the nitrogen plots on the folded section, the stem and leaf relationships are best considered by reference to the free-run section only.

A summary of the most important evidence is given in Table VI. In view of the results previously reported from the Station as to the greater nutritive value of leaf than of stem and as to the significance of leaf *qua* leaf, the figures in this table constitute perhaps the most informing data collected in connection with the trials

TABLE VI.—*To show for the different species and strains (for the grazing season as a whole) (1) the coefficient of palatability (percentage eaten of amount offering) for stem and leaf respectively; (2) the percentage of leaf in the herbage offering; and (3) the amount of stem and leaf respectively actually eaten (in lb. air-dry fodder per 1/150th acre plot). Data from the free-run section only of Penglais Field (first harvest year) are given for the nitrogen and control plots separately.*

Species and Strain.	Leaf.						Stem.			
	Per. cent in the herbage.		Per cent. eaten of amount offering.		Amount eaten.		Per cent. eaten of amount offering.		Amount eaten.	
	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.
Perennial rye-grass :—										
Indigenous 1412 ..	75	70	46	48	27	23	25	29	5	2
,, 1413 ..	71	73	33	34	12	12	16	28	3	5
Jædersk	71	69	39	26	9	5	34	13	4	2
Commercial	71	67	42	27	19	11	33	17	7	3
Italian rye-grass : Pedigree ..	65	66	50	46	18	12	31	26	7	3
Commercial	66	66	61	57	20	15	41	35	8	8
Cocksfoot : Indigenous 1640 ..	80	78	31	24	17	10	24	13	3	1
,, ,, 1163 ..	89	79	43	36	23	15	7	31	1	2
New Zealand ..	79	77	29	25	13	10	39	23	5	5
Commercial ..	82	77	60	58	31	19	29	19	3	3
Timothy : Indigenous 309 ..	80	74	45	46	14	11	10	24	1	3
,, 310 ..	77	75	66	64	20	17	41	33	4	3
Grinstad	76	72	60	61	16	11	31	45	3	7
Commercial ..	74	71	60	54	14	11	21	20	2	4
Meadow foxtail : Indigenous ..	87	83	44	31	28	17	17	25	2	1
Golden oat grass	60	53	44	28	19	7	36	27	13	7
Red fescue : Indigenous.. ..	85	86	20	18	17	13	7	5	1	1

under review. On the average of all the strains, nitrogen has not materially increased the proportion of leaf to stem in the herbage offering, and this is in keeping with earlier results†. In the present trials, however, nitrogen would seem quite appreciably to have added to the percentage contribution of leaf in the case of indigenous cocksfoot No. 1163 and of golden oat grass. In practically every instance nitrogen has, however, appreciably added to the amount of leaf eaten; it has even done so to a slight extent in the case of the indigenous red fescue. The increase has been most marked in the case of golden oat grass, of which species nearly three times as much leaf was eaten on the nitrogen- as on the control plots, the coefficient of palatability of the leaf also being very much higher on the nitrogen plots. This result is entirely borne out by the notes taken at the time of the several grazings. Other strains which have shown strikingly large increases in amount of leaf eaten under nitrogen are indigenous meadow foxtail, commercial and indigenous cocksfoot, and commercial perennial rye-grass.

If amount of leaf eaten is taken as our criterion of palatability, rather than total amount eaten or than a coefficient based on the sum of leaf and stem—and all the evidence so far collected at the Station seems rather to justify the adoption of such a standard—then we shall find that the species and strains arrange themselves in rather a different order of palatability. Timothy and Italian rye-grass have to give place to commercial cocksfoot, indigenous meadow foxtail and one of the indigenous perennial rye-grasses. The most striking figures in the table, which do less than justice to the obvious performance of the plots, are the exceedingly high values for "leaf eaten" on the nitrogen plots of commercial cocksfoot, indigenous meadow foxtail, and indigenous (No. 1412) perennial rye-grass. From the point of view of incremental applications of a nitrogenous fertilizer these results are of considerable significance, since they show that the returns which may be obtained under good management by the judicious use of such fertilizers are undoubtedly to a very real extent determined by both the species of grass and the strains of a particular grass to which they happen to be applied. The outstanding performance of commercial cocksfoot has to be largely discounted by the fact that this is a first harvest year result. As will be shown in a subsequent section, this strain falls off rapidly in yield in later harvest years, it does not in fact stand heavy grazing from year to year. Moreover, at the end of a 48-hour grazing period the notes taken at each grazing would suggest that the amount of leaf eaten of the best indigenous strain has been as great as that of the commercial strain even in the first harvest year.

These leaf data are exceedingly interesting in another connection. The greater palatability of the indigenous strain of cocksfoot No. 1163 than of No. 1640, of the indigenous strain of perennial rye-grass No. 1412 than of No. 1413, and of the indigenous strain of timothy No. 310 than of No. 309 has been referred to. The figures for leaf are, however, even more significant than those for stem and leaf together. It will be seen that the amount of leaf eaten of the more favoured strain is in each case and on both the control and nitrogen plots very greatly in excess of that of the less favoured strain. The amount of leaf eaten of the indigenous rye-grass No. 1412 on the average of the nitrogen and control plots has actually been more than twice as great as that of the comparatively similar indigenous strain No. 1413—the coefficient of palatability of the leaf of the former strain being also strikingly higher than that of the latter.

These differences between strains of comparatively similar growth-form and

†See Stapledon and Beddows (1926).

of not vastly dissimilar yielding ability are of great interest and tend to indicate the degree of complexity of the factors which influence the quality of a herbage plant. This very complexity is proof on the one hand of the enormous scope which exists for the improvement of herbage plants by careful breeding, and on the other hand emphasises the difficulties which have to be overcome in order to make the wisest possible selections and matings with the breeding material available. The results obtained from trials of this sort make it more than ever necessary to insist upon the fact that the plant breeder concerned with herbage plants has two distinct problems always before him ; namely, firstly, correctly to assess the potential herbage value of his material, and secondly, to produce strains breeding true to the desired characteristics, no matter how subtle and difficult of accurate definition these characteristics may be.

The figures in Table VI showing the comparatively small amounts of stem eaten in the majority of the species are further proof, if indeed such proof is necessary, of the overwhelming importance of leaf in estimations of the rival merits of both species and strains of grasses.

ACCESSIBILITY.

As has been shown in previous reports, accessibility has a considerable influence on the preference of sheep for a particular herbage. Like every factor influencing palatability accessibility has, however, to be considered together with the other factors which are operative. Certain broad conclusions may be drawn from the data derived from the present trials.

In the statement hereunder the average height of the leafage (in cm.) for the various species and strains, taking all the grazings into consideration (Penglais first harvest year), is set out :—

Average height of leafage in cm.

	Nitrogen.	*Control.*
Perennial rye-grass : Indigenous 1412	15.2	12.2
„ 1413	16.7	12.5
Jædersk	14.6	11.9
Commercial	18.8	14.1
Italian rye-grass : Pedigree	21.3	18.4
Commercial	20.4	20.2
Cocksfoot : Indigenous 1640	17.5	15.5
„ 1163	17.0	14.9
Commercial	22.4	19.8
New Zealand	19.3	16.1
Timothy : Indigenous 309	15.3	12.9
„ 310	13.5	12.0
Grinstad	14.9	13.5
Commercial	15.8	12.9
Meadow foxtail : Indigenous	17.3	15.4
Golden oat grass	21.7	19.4
Fine-leaved fescue 728	17.8	14.6
Average	17.6	15.1

With but a single exception (commercial Italian rye-grass) the addition of nitrogen has increased the average height of the leafage—the difference in favour of nitrogen for all the species and strains taken together being 2.5 cm. No doubt the greater accessibility of the nitrogenized herbage has been an important factor making for the fact that very decidedly more has been eaten off the nitrogen- than off the control plots. The greater accessibility of the upright and erect growing leafage of commercial cocksfoot than of the more spreading and lower growing indigenous has been a striking contrasting feature of the plots of this species and

has undoubtedly been an important, and perhaps the most important differentiating feature between the two strains. The greater accessibility of the commercial strain is even more accentuated under the influence of nitrogen, and it has been under nitrogen that commercial cocksfoot has shown to the greatest relative advantage in respect of amount of leaf eaten.

That accessibility is by no means the only factor influencing palatability is well shown by the figures for the two indigenous strains of perennial rye-grass, and for the two indigenous strains of timothy. In the case of both species it has been the less " accessible " of the two strains which has given the higher figures for amount of leafage eaten.

A general discussion of the inter-relation of the factors influencing palatability is deferred until the question of seasonal palatability has been disposed of.

Unsown Species.

Even during the first harvest year unsown species contributed quite appreciably to the aggregate " eatables " offering to the sheep from all the plots.

The chief contributing unsown species was bent grass, while Yorkshire fog was also present in considerable amount, and rough-stalked meadow grass was in decided evidence on Penglais Field. It was only by the second harvest year that wild white clover began to exercise a material influence on some of the plots. The strong growing and leafy indigenous cocksfoot (Bc 1163) maintained itself in a condition of the greatest purity, but, on the average of all the plots for the whole grazing season, unsown species contributed 8.8 per cent. to the eatables from the plots of even this strain. The commercial meadow foxtail, which from the outset was badly rusted and gave rise to poor plots, contained as much as 31.0 per cent. of unsown species in the eatables.

An examination of the coefficient of palatability of the unsown species for the different grazing dates gives a fairly good idea of the seasonal palatability of the bent grasses (the chief contributors to the unsown species).

Such an examination has been made of the figures for the plots as a whole, and also for the commercial meadow foxtail plots as such (where unsown species were most abundant). The coefficient was very low—quite as low as, or lower than that of the fine-leaved fescue—from the end of June to nearly the end of September.

It was fairly high (27 per cent.) in November and decidedly high in May (30-40 per cent.) Thus it would appear that at the commencement of the growing season and before the bents have started to make really substantial growth they are comparatively palatable, but that later in the year, even a three-week growing period is long enough for them to grow out of their palatable condition. Late in the autumn, even when not grazed very hard, they are relatively palatable, but in the winter unless grazed very hard they soon become burned and unpalatable—the palatability being still very low early in March.

On the average the coefficient of palatability of the unsown species (about 22 per cent.) was decidedly lower than that of all the species and strains under test, with the sole exception of red fescue. It is interesting to note, however, that the coefficient of palatability of the unsown species was higher on the plots of red fescue (the least palatable species) and of indigenous cocksfoot (relatively unpalatable) than on those of timothy (the most palatable species). The coefficient for the unsown species (chiefly bent) on the timothy plots was 18.4 per cent. and on the indigenous cocksfoot and red fescue plots it was about 23.0 per cent. This means of course that a sheep folded on a pure plot of a species of low palatability will eat more of the impurity offering—even although such impurity represents a species

of relatively low palatability—than it will when folded on a " pure " plot of a highly palatable species.

The influence of nitrogen on the palatability of the unsown species was quite marked on the free-run area (27 per cent. nitrogen ; 22 per cent. control), but was negligible on the " folded" area (18 per cent. nitrogen ; 17 per cent. control)—behaviour in keeping with that of the pure species and strains as such.

White Clover.

Wild white clover was sown with the various strains of grasses on the Cwm Field plots, on most of which it contributed in considerable amount to the herbage in the first harvest year. It had made a substantial "volunteer " appearance on the Penglais Field plots during the second and third harvest years ; it also established itself in appreciable amount as early as the first harvest year on Pond Field.

On this latter field exact quantitative data are available as to the amount of its contribution to the several plots, and as to the " amount eaten." On the average of all the control plots for the whole of the grazing season, white clover contributed 11.7 per cent. to the total eatables offering. The average coefficient of palatability of all the grasses was 42 per cent., while that of the white clover was 56 per cent. This suggests that white clover is a decidedly palatable species, although of course of palatable species growing together the one present in lesser amount is likely to be eaten to a relatively greater extent than the one present in larger amount.

The notes taken on the other fields at the several grazings definitely show, however, that white clover is decidedly a palatable plant. It was perhaps relative to the grass species best grazed—and on all plots alike—at the mid-April grazings ; that is to say, at a date before it had started really active growth and when it was growing far less vigorously than the majority of the grasses. The extent to which it was then eaten is interesting in view of the use to which ordinary white Dutch clover is put, for example in Dorset, for spring grazing with sheep.

The behaviour of wild white clover in relation to palatability throughout the grazing season as a whole was variable and depended to a large extent upon the species with which it was growing, and upon the manner in which the sheep were controlled. On the free-run areas the sheep would seem to have been drawn to particular plots, not so much on account of abundance of white clover as on account of the nature of the grass. Thus on the timothy plots (Penglais, second and third harvest years), especially on those of the indigenous strains, the white clover was invariably well eaten—the leafage of the timothy and of the white clover being densely intermingled and as a unit particularly well grazed.

There was quite as much white clover on the red fescue plots as on the timothy plots, but the clover was not nearly as well grazed. There was none the less evidence to show that on the fescue plots at most of the grazings the white clover was eaten to an altogether greater extent than the fescue itself. On the Italian rye-grass plots, taking the evidence as a whole, the sheep would seem to have preferred the Italian rye-grass as such to the volunteer white clover. Seeds mixture plots at various centres have invariably shown that plots sown with a mixture including wild white clover have been better grazed than those with no white clover in the mixture. In such trials, however, the grasses used in both series of mixtures have been the same, so that selection had not been influenced by the grasses as has been the case in the experiments immediately under review.

On the folded plots connected with the present trials, the less palatable species like the red fescues were better grazed in the second and third harvest years than in the first, and the notes taken at the several grazings leave no doubt that this was

in large measure, though probably not entirely, due to the sheep taking the fescue with the then abundant and more palatable white clover.

Another point of some interest in connection with the folded plots was that the sheep did not eat the highest proportion of white clover on those plots where it was present in the greatest amount, that is to say, on plots where the grass had largely failed and where clover was the chief eatable offering.

When growing with relatively unpalatable species like *Bromus arvensis* and Yorkshire fog, the white clover was eaten to a far greater extent than the grass when the grass was in its stemmy and most unpalatable stage. When, however, the grass was leafy and short, any selection in favour of the clover was not pronounced. This was also noteworthy on the brown top plots, for when the grass was in a favourable growth stage the *Agrostis* and the white clover were well mingled, and the two species were uniformly and well grazed.

The white clover was grazed by sheep, at least to some extent, at all stages of growth, except that the ripening seed heads were never touched; fresh flower heads were, however, eaten on some of the plots to quite an appreciable extent.*

SEASONAL PALATABILITY.

For reasons previously explained seasonal palatability is influenced to a considerable degree by the idiosyncrasies of the sheep and on this account the free-run data are more reliable than the folded. The evidence from all the experiments, however, is remarkably confirmatory in respect of the more important points at issue and may usefully be discussed in general terms.

A comparison of the "amounts eaten" at the different dates on the free-run and folded plots is interesting (the data are very extensive and are not presented in detail). At most of the dates and in the case of the majority of the species and strains the "amount eaten" is greater on the folded plots. The amount may be very considerable. In May it has reached as high a figure as 13 lb. of air-dry leafage (in 24 hours) for meadow foxtail and over 7 lb. for commercial cocksfoot and indigenous timothy. When, however, the herbage is scant the state of affairs is different; thus on November 8th the "amounts eaten" respectively from the folded and free-run plots are not very different. On March 26th, when only a few species and strains were yielding reasonably abundant leafage, in most cases the greater amount was eaten off the free-run plots. This was particularly noteworthy in respect of the plots yielding the most leafage as is shown by the comparison hereunder:—

	Amount of leafage eaten (in lb. dry fodder) per 1/150th acre plot in 24 hours. Nitrogen plots.		
	Indigenous cocksfoot.	*Indigenous meadow foxtail.*	*Indigenous red fescue.*
Free-run	2.4	5.1	4.4
Folded	1.4	1.6	0.6

At this time of the year the sheep would of course have been drafted on to the

*This fact indicates the extent to which wild white clover can perpetuate itself by self-seeding in sheep pastures and suggests the great importance of self-sown (and dormant) seed in relation to the well-known benefits from basic slag. Sheep tethered on experimental blocks of pure white clover in an advanced stage of flowering and seed ripening would not graze such adult plants to any extent and had to be removed.

TABLE VII.—*To show* (1) *the amount of leaf eaten (in lb. air-dry fodder per 1/150th acre plot) at each of the eight grazing dates in the first harvest year, and* (2) *the coefficient of palatability of total grass (leaf and stem). Data on the free-run Penglais Field.*

Species and strains.		May 2.		May 25.		June 22		July 12.		Aug. 16.		Sept. 22.		Nov. 8.		March 26.	
		Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.
Perennial rye-grass : Indigenous	(1)	1.5	1.7	6.6	3.1	3.9	2.7	3.1	2.2	2.2	2.6	4.1	5.2	3.3	3.7	1.0	1.7
	(2)	22	24	72	47	38	49	43	34	23	34	51	52	40	59	27	36
Perennial rye-grass : Commercial	(1)	3.6	1.5	4.4	1.0	0.5	0.1	0.7	0.3	3.3	2.1	1.5	3.3	3.5	0.1	1.7	2.1
	(2)	31	10	73	45	29	5	13	5	44	36	44	36	53	1	55	81
Italian rye-grass	(1)	4.8	4.0	4.1	1.7	2.8	2.7	1.1	1.2	2.0	1.5	1.7	1.1	1.9	0.9	0.8	0.7
	(2)	51	43	73	47	59	50	35	38	30	34	32	32	43	36	71	81
Cocksfoot : Indigenous.	(1)	0.8	3.5	3.6	2.7	3.5	2.8	1.2	0.7	3.5	1.8	5.3	1.8	2.1	0.3	2.4	1.8
	(2)	13	46	58	49	37	30	20	16	41	30	51	31	44	6	40	49
Cocksfoot : Commercial	(1)	5.6	1.7	3.9	3.3	6.1	4.3	1.2	1.9	8.5	4.4	2.9	1.8	1.3	0.6	1.3	1.1
	(2)	48	12	50	66	66	58	32	45	64	63	57	54	46	41	53	68
Timothy : Indigenous	(1)	2.5	3.2	4.9	1.6	4.3	2.9	0.5	1.2	1.1	1.8	2.3	1.7	0.9	0.9	0.8	0.5
	(2)	49	59	80	30	62	62	14	32	20	37	43	42	36	49	63	65
Timothy : Commercial	(1)	3.8	3.7	3.0	2.0	3.0	1.2	1.0	0.7	1.9	1.9	2.0	1.2	0.2	0.2	0.6	0.4
	(2)	51	51	61	71	57	44	41	23	37	40	44	43	23	31	59	80
Meadow foxtail : Indigenous	(1)	2.8	0.0	4.8	0.9	4.3	1.7	2.7	1.8	2.7	4.8	2.8	2.9	2.9	1.3	5.1	4.1
	(2)	21	0	71	30	53	19	38	24	20	50	33	43	43	35	68	70
Fine-leaved fescue : Indigenous	(1)	1.3	0.4	0.7	1.1	2.2	0.9	1.5	1.0	2.5	2.9	2.6	1.7	2.3	2.0	4.4	3.5
	(2)	9	3	13	12	13	12	14	10	15	23	18	16	19	19	36	40
Golden oat grass	(1)	7.0	3.5	2.5	0.5	3.0	0.3	1.8	0.1	0.5	0.9	2.2	1.3	0.5	0.3	1.1	0.5
	(2)	55	47	50	26	62	23	23	7	5	11	37	28	18	10	61	48

plots from a very poor and scant herbage. It appeared that when folded on an abundant and succulent herbage—with no scope for selection—the sheep were quite unable to adjust themselves to the sudden change of diet. When, however, they were offered poor and semi-dried leafage as well as succulent leafage (as was the case on the free-run area) they gave enough attention to the nutritious and succulent herbage to do full justice to what was offering. This is an interesting piece of evidence, confirmatory of general experience, and shows that if one has produced a field of exceptionally early spring keep, the sheep should only be given short periods upon it, or be given the run of the '" early " area along with that of an ordinary late and non-succulent area.

Attention will now be confined to the evidence from the free-run areas. The data are tabulated only in the case of the Penglais Field (first harvest year)—see Table VII.

A general study of Table VII reveals the fact that the species and strains from the seasonal point of view are highly complementary to each other, and thus a range of species and strains affords the maximum of eatable herbage over the longest season. In this connection it is the behaviour of the species and strains during lean periods which is so important. The lean periods (when growth is at least possible) are March and early April, and from the middle of July onwards. Dealing with the latter period first, it will be noted that on July 12th indigenous meadow foxtail and indigenous perennial rye-grass assume a position of outstanding importance relative to amount of leafage eaten—the coefficient of palatability also being high. On August 12th commercial cocksfoot stands in a class by itself—it must be remembered that this is first harvest year data. Indigenous meadow foxtail is again very good ; very interesting is the high place taken by indigenous red fescue with a large amount of leaf actually eaten although the coefficient of palatability remains low. Indigenous cocksfoot makes a very good contribution on the nitrogen plots. On September 22nd indigenous perennial rye-grass, on the average of control and nitrogen plots, is the most valuable strain, although the greatest amount of leafage has been taken from the nitrogen plots of indigenous cocksfoot. The indigenous meadow foxtail and indigenous red fescue again make a good showing, although the coefficient of palatability remains low. On November 8th, the three most important strains are indigenous rye-grass, indigenous meadow foxtail and indigenous red fescue (still with a low coefficient of palatability).

The results for the early spring (March 26th) are even more interesting ; the indigenous red fescue and indigenous meadow foxtail stand in a class by themselves. In appearance the plots of these strains were in marked contrast to all the others. The leafage was very abundant, beautifully green and not in the least burned, the amount of leafage eaten being actually greater than that taken from any species or strain in November : it was indeed greater than the amounts taken in September from all strains except indigenous cocksfoot and indigenous perennial rye-grass. A further point of great significance was the fact that at this spring date the red fescue had quite a high coefficient of palatability, the coefficient being actually twice as high as its own average for the whole grazing year. Data obtained on April 16th in the following year (1929) confirmed absolutely the outstanding early spring preference of these two strains.

Further examination of the table brings out the following interesting facts. It will be noted that the highly palatable species Italian rye-grass and timothy

*What is here said relative to red fescue in particular should be considered in conjunction with the evidence discussed under seasonal productivity (see page 68).

retain a remarkably level scale of palatability throughout the season. Italian rye-grass drops a little in July, August and September ; this is due to a marked tendency to stem and panicle production—indeed the drop would be greater were it not for the fact that the stem *qua* stem of Italian rye-grass is eaten to a greater extent than that of other grasses. The timothy drops a little in July—again due to stem production ; this is most marked on the indigenous plot (nitrogen). This strain produces an excess of small panicle-bearing stems at this date under the influence of nitrogen. Perennial rye-grass is prone to fall off very decidedly in palatability during June and July, the indigenous strain maintaining its position far better than the commercial—the latter strain being altogether more prone to stem formation. Commercial cocksfoot maintains a very level standard of palatability, the indigenous, on the other hand, fluctuates considerably.

The indigenous red fescue only has a really high coefficient of palatability early in the spring. Golden oat grass shows a greater fluctuation than any other species. The low coefficients are, however, usually associated with periods of excessive inflorescence production. They are only to a relatively slight extent associated with periods of excessive stem and sheath (without inflorescences) production, for, as has already been shown, the " stem " of this grass relative to its own leafage is much more palatable than in the case of other species.

From the point of view of the influence of nitrogen, it will be noted that the greatest benefit in terms of amount of leaf eaten has been on May 25th ; that is to say, just when the benefit is least desired. On the other hand, of course, gains, if not relatively very great, are of immense value *per se* in March, and it will be seen that at that date the leafage eaten of meadow foxtail and red fescue has been materially increased by nitrogen.

Further particulars as to seasonal palatability may most usefully be given in the form of a series of notes (data from all the experiments for both free-run and folded areas) with reference to each species under test.

Italian rye-grass. This grass maintains a very high level of palatability ; it is peculiarly palatable early in the year. In the second and subsequent harvest years, when the plots are thinning, the palatability of Italian rye-grass is more than usually striking—under free-grazing the sheep immediately defoliate these plots. It has been pointed out that the stem of Italian rye-grass is more palatable than the stem of other grasses. During periods of stem-production the plots none the less drop somewhat in palatability, and this is apparent as much in August as earlier in the year. Under an extended rest period the stems of even Italian rye-grass tend to be neglected.

Perennial rye-grass. The commercial strain may become decidedly stemmy quite early in June when it will be largely neglected—this is particularly marked if conditions for growth have been very favourable. In some of the trials there was a tendency for the leaves to be tip-burned in July, but this did not affect palatability to any marked extent.

In November there was a quite decided tendency for the leaves to be burned, (although of course not nearly to the same extent as cocksfoot), and this was true of the indigenous as well as of the commercial strain. On the nitrogen plots the burn was less in evidence and more than twice as much leafage was eaten as on the control plots.

When the period of rest is extended, the palatability of perennial rye-grass is probably adversely affected to a less extent than in the case of any other species.

Cocksfoot. The difference between the indigenous and commercial strains is particularly marked at the first grazing in the spring (usually early April). The indigenous strain will have made a certain amount of growth during the winter and will not have fairly started its spring growth. In consequence, the leafage consists of much " old " and very little " young" growth, and the plots are almost entirely neglected. The commercial strain, on the other hand, will have started active spring growth and will be green and succulent and exceedingly palatable. The contrast in palatability—though not quite so exaggerated—is maintained throughout May. At this period the sheath of the commercial strain is eaten to a very appreciable extent, and the plots are liable to be grazed absolutely to ground level. The indigenous strain attains to a very high degree of palatability during June, and is relatively good during August and September. The leafage of cocksfoot usually begins to burn fairly early in October ; while a drop in pala-

tability tends to show itself even before burn is apparent. Not only burn as such, but also palatability, even when independent of burn, is very sensitive to the length of the rest period at this time of the year. In one experiment the rest period was extended to 34 days (October) with the result that the cocksfoot was hardly touched—whilst the palatability of the perennial rye-grass, for example, was not adversely affected. The long and burned herbage of the cocksfoot was eventually eaten on the folded area. By November the burn had materially increased and the leafage was neglected. As in previous experiments the New Zealand strain remained the most winter-green, closely followed by indigenous—the Danish showing the greatest winter burn. Winter-greenness was maintained better on the nitrogen plots than on the control plots.

Although the greatest productivity possible was obtained from cocksfoot under the high manuring and prolonged rest periods of these trials, at no date was the grass refused by the sheep when the grazing period was extended beyond 24 hours, and, as stated above, when the rest period was reduced the leafage was taken with evident relish. In the fourth harvest year when the growth was less rapid it was particularly noted that even on the basis of a month's rest, the indigenous cocksfoot, equally with the indigenous perennial rye-grass, was always grazed bare. From the point of view of the management of cocksfoot no harm will be done if considerable growth is permitted provided always the plants are periodically grazed bare.

Timothy. This grass, at all times highly palatable, is quite extraordinarily palatable early in the year when the growth is not considerable. In March and early April on some of the plots over 80 per cent. of the leafage offering had been taken. If the rest period is reduced or the stocking extra heavy (on free-run area) the small plants may be actually uprooted ; this occurred at more than one grazing.

The decided tendency towards inflorescence production on the part of the indigenous timothy during July was noted in connection with all the trials, and in each case nitrogen increased this tendency—and at this particular grazing reduced the palatability.

Meadow foxtail. The indigenous strain was undoubtedly one of the most interesting included in the experiments. The excellence of the early spring performance has been sufficiently emphasised. It should be added that at the all-important March grazing this strain was one of the very first to attract the attention of the sheep. The leafage is also abundant and palatable in the early autumn, but by November, although the leafage may still be relatively abundant, it is not nearly as palatable as that of perennial rye-grass.

Tall oat grass. This species was only included in one trial. It was grazed hard to the ground at the end of April and early in May.

Tall fescue. Like tall oat grass, this species was very hard grazed early in the spring, indeed in April (Pond Field ; folded plots only) no grass was grazed harder. It was also grazed particularly hard in the middle of August.

Crested dogstail. Except when in abundant stem this grass is well grazed. It was in its most stemmy condition early in June. In August, crested dogstail was one of the most palatable species, the leafage being comparatively abundant and very well eaten.

Red fescue. The period of a month's growth was too long for this species. At one of the grazings (July 12th, Penglais) the rest period had only been 15 days, and it was noted that this species was then altogether better grazed than usual for the time of the year. The indigenous strain was very much more palatable than the Chewing's fescue. There is some evidence for thinking that red fescue as such is somewhat more palatable in its second and third harvest years than in the first. Early in September in the third year on Penglais the indigenous strain was a mass of vivid green leafage. The leafage appeared to be particularly brittle and succulent on the nitrogen plot at this date, and was unusually well grazed ; the evidence as a whole, however, rather indicating that this grass always tends to be relatively well grazed from the middle of August to the middle of September. The outstanding position taken by the indigenous strain in March has been emphasised. It should be added that the indigenous strain is altogether more winter-green than Chewing's fescue.

Golden oat grass. This species is early and is then highly palatable. In April, on some of the plots it was grazed to ground level. The sheath of golden oat grass, despite its hairiness, is more palatable compared to its own leafage (also decidedly hairy) than is the case in other species. The palatability of the leafage has been greatly increased by the addition of nitrogen, perhaps particularly during May and June. On June 21st the amount of this grass eaten on the nitrogen plot was four times as great as that eaten on the control. As previously shown, this grass is very prone to run to inflorescence, and then it is not palatable. It produces abundant secondary inflorescences in August, when it appears to be even less palatable than when first in flower.

Yorkshire fog. The seed sown was " cleanings " from commercial perennial rye-grass. The plants resulting from the seed tended to differ from the ordinary indigenous Yorkshire fog (which made a volunteer appearance to some extent on most of the plots—those of all species—in all the experiments) in the same general way as commercial perennial rye-grass does from indigenous. The plants *ex* commercial seed were much more stemmy and earlier than the true (and volunteer) indigenous.

On the plots (the *ex* commercial rye-grass strain) the plants run into stemminess almost earlier than any other species—the plots were already stemmy in April and the stemmy condition was maintained right into June. During these months the plots were badly grazed—the stems being entirely neglected, or, if bitten off, dropped. Indigenous (volunteer) and more leafy plants occurring both in the Yorkshire fog plots and amongst other species were very much better grazed. During July when there was little or no tendency to stemminess the plots were very well grazed ; they were also particularly well grazed in October.

Yorkshire fog is unlike golden oat grass in that the contrast between the palatability of stem and leaf is exceptionally pronounced.

Sweet vernal grass. The commercial seed of sweet vernal grass gives rise to plants in marked contrast to the indigenous (and volunteer) representatives of the species. The commercial strain suffers from all the defects above noted for Yorkshire fog, and tends to be excessively stemmy and unpalatable except for a short period at mid-season.

Chicory. Although, as has been shown by previous seeds mixture trials, sheep readily graze chicory in a mixed sward, they did not appear to relish this species grown as a pure plot on Pond Field.

SUCCULENCE.

The outstanding character influencing palatability is succulence. Without attempting to discuss " succulence " in precise physiological terms, the evidence from these experiments suggests that " succulence" can be looked at in a broad empirical way and in a manner that is highly suggestive in so far as the control of the grazing animal on different types of pasture is concerned. A very useful hypothesis may be expressed as follows :

(a) The leafage of a grass will be succulent and palatable in proportion as it is growing fast.

(b) Rapidity of leaf growth varies for every species and strain. Climatic and soil conditions can only act upon the inherent capacities for rapidity of growth *qua* rapidity of growth of the several species and strains.

(c) Leafage falls off in succulence and palatability in proportion as rapidity of growth slows down, and palatability drops off very rapidly when the growth of individual leaves comes to a standstill. All species and strains have their inherent propensities in these respects.

We may give a few examples to illustrate the above " rules." The leafage of cocksfoot grows extremely fast (per unit of length) ; that of rye-grass not so fast ; that of the fine-leaved fescues altogether more slowly.

The leaves of perennial rye-grass will continue to make some sort of growth for a longer period *per se* than will the leaves of cocksfoot—the leaves of the fine-leaved fescues also continue to grow slowly for a long time. When it comes to a question of strain we may note, for example, that the leaves of commercial cocksfoot grow decidedly faster than those of indigenous cocksfoot.

It follows from what has been said that commercial cocksfoot would grow out of a palatable condition more quickly than indigenous—but if grazed while still actively growing, the former strain will be much the more palatable. It is probable that the reason for perennial rye-grass being more palatable than most grasses when the leafage is approaching the adult condition is that it grows fast enough to be succulent, and continues to grow—even if slowly—for a long period.

It is evident, moreover, that in the case of grasses, the leaves of which grow very slowly, *e.g.*, the fine-leaved fescues and (although perhaps to a less extent) the bent grasses, the herbage will only be palatable if grazed when the leaves are making growth with the maximum rapidity of which they are capable, that is to say, if the leaves are grazed very young, or in other words, when the rest period is very short. The matter can be expressed numerically in rather a striking manner. The different species could be assigned marks for their inherent rapidities of growth. Cocks-

foot would perhaps be placed at 100 (the maximum) ; red fescue at 30. Then a rough measure of the coefficient of succulence (which would be an expression of palatability) at any particular moment would be given by dividing the "rapidity of growth" by the number of days that had been allowed for growth, *i.e.* by the length of the rest period.

Thus if the period of growth was 30 days we would have for cocksfoot $\frac{100}{30} = 3.3$, and for red fescue $\frac{30}{30} = 1.0$.

This would mean that in order to provide the animal with red fescue leafage of approximately the same degree of succulence as 30-day old cocksfoot we should have to offer him 10-day old fescue, for $\frac{30}{10} = 3.0$.

Obviously the matter is not as simple as this, and other factors would have to be introduced for the several species before we could arrive at a formula which would allow of really correct comparisons.

This empirical hypothesis and its numerical expression do, however, serve to emphasise an extraordinarily important manner in which species and strains differ amongst themselves. This view as to succulence—generalized and empirical as it is—accords absolutely with the observed facts in relation to the behaviour of the chief species of grass which contribute to our pastures. This matter will be considered in further detail when dealing with the general conclusions to be drawn from the experiments as a whole.

There is some evidence for thinking that succulence and, therefore, palatability also are influenced by the moisture content of the leafage.* It has been shown that the " amounts eaten " from the nitrogen plots have been very much greater than from the control plots. A comparison was made at three separate dates of the moisture content of the herbage of the nitrogen and control plots respectively. Very dry and sunny days were selected. The herbage representing pure species and strains was rapidly cut and immediately weighed in the field laboratory and then oven-dried. The results showed that in all cases the nitrogenized herbage gave the higher moisture content. The excesses in favour of nitrogen were as under :—

Penglais Field,	first	harvest	year,	2.0 per cent.
,, ,,	second	,,	,,	1.4 ,,
Pond Field,	first	,,	,,	1.7 ,,

These differences are not considerable but their significance should not be overlooked for they serve to indicate the possible importance of a matter which is admittedly difficult to subject to critical investigation.

HAY AND AFTERMATH.

Hay and aftermath data are available from two of the experiments : Penglais, first harvest year, and Pond Field, first and second harvest years. Yield and other data are presented in Tables VIII, IX and X. The chief points brought out will be dealt with under suitable headings.

The Influence of Nitrogen.

Tables VIII and X indicate that the addition of nitrogen to the phosphatic dressing has had a very decided influence on hay *cum* aftermath yield. On the average of all the species and strains and of both the experiments this increase has

*See Stapledon and Jones (1927).

TABLE VIII.—*To show* (1) *the yield of hay with aftermath*; (2) *the percentage increase over hay yield due to the contribution of aftermath*; (3) *the percentage of leaf in the total produce of hay and aftermath, and* (4) *the percentage increase of the yield of hay with aftermath for nitrogen over that for control. Yields as pure species and strains in lb. of air-dry fodder per 1/100th acre. Penglais Field, first harvest year.*

Species and strain.	Nitrogen.			Control.			Percent. increase of total yield for nitrogen over control.
	Yield of hay with aftermath.	Percent. increase due to aftermath.	Percent. leaf in yield of hay with aftermath.	Yield of hay with aftermath.	Percent. increase due to aftermath.	Percent. leaf in yield of hay with aftermath.	
Perennial rye-grass indigenous 1412	79.4	27	49	31.8	38	55	149
,, ,, 1413	82.7	18	29	30.0	24	37	176
,, Jaedersk	62.3	22	39	25.1	22	35	148
,, commercial	82.3	18	24	36.2	12	18	127
Italian rye-grass pedigree	62.1	24	22	28.2	23	24	120
,, commercial	59.0	27	18	30.7	22	9	92
Cocksfoot indigenous 1640	75.8	34	58	19.3	32	52	294
,, ,, 1163	68.0	33	56	26.8	34	57	154
,, New Zealand	70.0	22	41	28.2	30	49	148
,, commercial	61.8	29	49	38.1	15	25	62
Timothy indigenous 309	52.2	27	35	26.0	35	56	100
,, Grinstad	49.4	19	50	25.0	18	32	98
,, commercial	31.4	39	30	24.6	28	54	28
Meadow foxtail indigenous 284	43.8	34	75	21.6	31	74	103
,, commercial	47.7	26	38	23.1	19	39	106
Golden oat grass	63.7	36	18	42.6	21	18	49
Chewing's fescue	56.4	50	34	24.8	40	37	128
Average for all grasses	61.8	29	39	28.3	26	39	118
Average for indigenous strains	66.3	28	46	26.2	31	51	153
Average for commercial strains	56.4	28	32	30.5	19	29	85

TABLE IX.—*To show* (1) *the yields of hay with aftermath in lb. of air-dry fodder per* 1/100*th acre plot for the first and second harvest years and* (2) *the percentage increase over hay yield due to the contribution of the aftermath. Pond Field.*

Species and strain.	No. of strains averaged.	1929.				1930.			
		Nitrogen.		Control.		Nitrogen.		Control.	
		Yield of hay with aftermath.	Percent. increase due to aftermath.	Yield of hay with aftermath.	Percent. increase due to aftermath.	Yield of hay with aftermath.	Percent. increase due to aftermath.	Yield of hay with aftermath.	Percent. increase due to aftermath.
Perennial rye-grass : indigenous ..	2	36.6	29	24.2	35	25.6	25	17.3	44
,, New Zealand ..	2	53.5	25	22.7	21	25.9	14	16.9	18
,, commercial ..	3	56.6	19	30.5	15	29.0	13	20.0	22
Italian rye-grass : pedigree	1	63.6	26	20.0	18	16.7	28	6.4	24
,, commercial ..	2	61.5	27	19.3	33	20.3	23	15.1	36
Cocksfoot : indigenous	7	45.0	34	19.3	43	51.1	42	23.2	63
,, New Zealand	1	49.7	32	28.3	38	51.8	42	25.0	42
,, commercial	8	46.8	32	28.7	29	48.3	40	29.3	45
Timothy : indigenous	2	36.3	28	13.8	33	24.6	23	7.9	27
,, commercial	3	35.9	19	12.6	21	17.3	27	9.6	24
Meadow foxtail : indigenous ..	2	23.3	26	9.7	37	22.4	45	7.0	57
,, commercial ..	1	13.1	29	8.3	36	10.2	44	7.1	47
Fine-leaved fescue : indigenous ..	1	56.6	32	23.3	36	49.3	29	31.0	36
,, Chewing's ..	1	18.2	40	6.7	37	35.7	20	22.6	31
Meadow fescue : commercial	2	62.5	18	25.3	25	34.6	28	23.8	30
Crested dogstail : commercial ..	1	12.9	15	4.9	80	10.9	2	2.4	8
Rough-stalked meadow grass : commercial	1	15.1	17	2.7	17	2.5	40	1.1	82
Tall oat grass : commercial	1	52.5	19	*	—	9.1	44	—	—
Tall fescue : commercial	1	*	—	39.2	26	—	—	25.5	33
Sweet vernal grass : commercial ..	1	34.5	21	26.6	7	26.4	4	18.8	12
Yorkshire fog : commercial	1	48.4	23	28.8	24	41.8	28	27.4	31
Agrostis : brown top : New Zealand	2	14.9	37	9.8	45	36.0	41	32.0	37
Chicory	1	57.9	27	44.2	23	19.7	34	10.8	38
Average for indigenous strains ..	15	43.6	29	18.3	34	31.6	32	15.5	42
Average for commercial strains of the same species	18	38.7	28	17.7	29	26.8	28	17.3	34

*No plot.

TABLE X.—*To show* (1) *the sum of the hay with aftermath yields, in lb. of air-dry fodder per 1/100th acre plot, for the first and second harvest years*; (2) *the percentage increase of nitrogen over control, and* (3) *the percentage of panicle plus stem shoots in the sum of the hay and of the aftermath for the two years. Pond Field.*

Species and Strains.	No. of strains averaged.	Sum of hay with aftermath yield for two years.		Percent. increase of nitrogen over control.	Percent. panicle plus stem shoots in hay.		Percent. panicle plus stem shoots in aftermath.	
		Nitrogen.	Control.		Nitrogen.	Control.	Nitrogen.	Control.
Perennial rye-grass : indigenous ..	2	62.2	41.5	50	70	61	13	26
,, New Zealand	2	79.4	39.6	100	91	92	38	46
,, commercial	3	85.6	50.5	70	96	96	32	35
Italian rye-grass : pedigree ..	1	80.3	26.4	204	83	83	63	49
,, commercial ..	2	81.8	34.4	138	96	94	62	68
Cocksfoot : indigenous	7	96.1	42.5	126	40	28	0	0
,, New Zealand ..	1	101.5	53.3	92	39	44	1	1
,, commercial	8	95.1	58.0	64	56	38	0	1
Timothy : indigenous	2	60.9	21.7	180	84	92	60	73
,, commercial ..	3	53.2	22.2	140	91	93	58	43
Meadow foxtail : indigenous ..	2	45.7	16.7	174	13	15	5	5
,, commercial	1	23.3	15.4	52	19	4	1	0
Fine-leaved fescue : indigenous ..	1	105.9	54.3	95	74	71	0	0
,, Chewing's ..	1	53.9	29.3	84	70	88	1	0
Meadow fescue : commercial ..	2	97.1	49.1	98	72	85	2	11
Crested dogstail : commercial ..	1	23.8	7.3	226	97	83	42	33
Rough-stalked meadow grass : commercial	1	17.6	3.8	363	68	68	42	49
Tall oat grass : commercial ..	1	61.6	—	—	97	—	89	—
Tall fescue : commercial ..	1	—	64.7	—	—	37	—	3
Sweet vernal : commercial ..	1	60.9	45.4	34	92	99	15	31
Yorkshire fog : commercial ..	1	90.2	56.2	61	96	96	6	2
Agrostis : brown top : New Zealand ..	2	50.9	41.8	22	89	87	70	68
Chicory	1	77.6	55.0	41	—	—	—	—
Average for indigenous strains ..	15	75.2	33.8	138	61	59	24	26
Average for commercial strains of the same species	18	65.5	35.0	92	71	69	26	25

amounted to as much as 116 per cent. The least effect was shown on brown top (22 per cent.) and the greatest on rough-stalked meadow grass (363 per cent.) and indigenous cocksfoot (294 per cent.). A very interesting fact is that the indigenous strains have responded to nitrogen to an altogether greater extent than the commercial. Thus, on Penglais the indigenous strains have given an increase of 153 per cent. compared to 85 per cent. by the commercial; while on Pond Field the comparative figures were 138 per cent. and 92 per cent. respectively. In so far as hay *cum* aftermath is concerned cocksfoot as a whole (all strains) has responded better to nitrogen than has perennial rye-grass (all strains)—this, however, is largely due to the better aftermathing ability of cocksfoot.

Nitrogen has not to any material extent increased the percentage of leaf in the hay *cum* aftermath; it has, if anything, slightly reduced it in the case of the indigenous strains, and slightly increased it in the case of the commercial. In both commercial and indigenous strains the tendency is for nitrogen to increase the percentage of panicle and stem shoots in the hay. This latter effect is particularly noteworthy in the case of indigenous cocksfoot and is fully in keeping with results from earlier trials.

The indigenous strains ordinarily tend to give a higher percentage increase due to aftermath than do the commercial. On the nitrogen plots, however, the commercial strains are more favoured relatively than the indigenous (in respect of aftermath), with the result that there is no material difference in percentage increase " due to aftermath " between indigenous and commercial on these latter plots. Nitrogen shows to much better effect on the yield of hay *cum* aftermath than it does on pasture. Thus on the basis of all the data available (see subsequent section for pasture data) we can make the comparison hereunder.

	Increased yield due to nitrogen.	
	Hay *cum* aftermath.	Sum of pasture cuts.
Indigenous strains	144 per cent.	55 per cent.
Commercial strains	88 ,,	36 ,,

This result is in keeping with earlier findings, which have shown that, in the case of pasture, nitrogen produces an increase of yield in inverse proportion to the intensity of the defoliation.

Comparison Between the Yields of the First and Second Harvest Years.

Reference to Table IX (Pond Field) shows that on the average the hay *cum* aftermath yields have been less in the second harvest year (1930) than in the first (1929), and this despite the fact that 1930 must be regarded as the more favourable of the two years.

It will be noted that a greater relative decrease of yield has shown itself on the nitrogen- than on the no-nitrogen plots. This is an exceedingly interesting state of affairs which will be considered in greater detail when dealing with the pasture yields.

The falling yield from year to year has been remarked upon in previous publications*, but it was thought possible that such a state of affairs might not occur under the influence of complete manuring. That it does so occur is a matter of considerable practical significance.

The species and strains vary considerably in their ability to maintain a high yield into the second year, and it is interesting to note that brown top (*Agrostis*

*See Stapledon and Davies (1928 and 1930).

vulgaris) has yielded decidedly better (both with and without nitrogen) in the second year than in the first, while Yorkshire fog has yielded practically as well in the second as in the first year. The fine-leaved fescues have also maintained (or increased) their yield in the second year. Of more orthodox grasses, indigenous cocksfoot (on both nitrogen- and no-nitrogen plots) has yielded better in the second than in the first year, while meadow foxtail has yielded practically as well in the second as in the first year.

Even the indigenous strains of perennial rye-grass and timothy have dropped in yield quite appreciably in the second year. The behaviour here noted for the several species and strains is of considerable importance with reference to the preparation of long-duration hay leys, for which purpose it would seem evident that a good indigenous strain of cocksfoot must be regarded as of the greatest value. Indigenous red fescue, representing a species not usually regarded as of much importance on meadows, has also given excellent results in the second year (surpassing both the rye-grasses and timothy) and would, therefore, seem to rank as a really important long-duration hay plant—an implication that has been foreshadowed by previous trials. The high place taken by meadow fescue and brown top in the second year is also not without considerable practical significance.

Aftermath Production.

The increase in aggregate yield (hay and aftermath) due to aftermath has been shown in previous experiments to vary very much as between species and strains and as between season and season.* The conditions for aftermath growth were decidedly favourable in each of the three years here under review, and it will be noted that the average figures (for all species and strains) are very similar—representing an increase (due to aftermath) of about 30 per cent.

As in previous experiments, commercial perennial rye-grass and crested dogstail show relatively poor aftermathing ability, while in the trials under review commercial timothy has given rather a better aftermath than is usual. Indigenous cocksfoot and indigenous meadow foxtail have again shown their excellent aftermathing ability—as have the fine-leaved fescues. Yorkshire fog, meadow fescue, tall fescue and brown top are all species which have shown to good advantage in the aftermath.

As in previous experiments, Italian rye-grass, timothy and tall oat grass have all produced considerable quantities of secondary inflorescences in the aftermath, and it is interesting to note that brown top has behaved in a similar manner. Crested dogstail, sweet vernal grass, rough-stalked meadow grass and perennial rye-grass are also species with a decided tendency to panicle production in the aftermath. Indigenous perennial rye-grass, however, develops far fewer aftermath panicles than does commercial. Cocksfoot, meadow foxtail, tall fescue, the fine-leaved fescues and Yorkshire fog are grasses of which the aftermath consists almost exclusively of leafage.

Panicle Shoots and Leaf Contribution in Hay (See Tables VIII and X).

Meadow foxtail is here seen (as in previous experiments) to produce fewer panicle shoots in the hay than any other species, the hay and aftermath being predominantly leafy. The leaf contribution of the indigenous strain to the sum of hay and aftermath is 75 per cent., compared to 56 per cent. in the case of the highly leafy indigenous cocksfoot. At the other extreme we have grasses like crested dogstail, tall oat grass, sweet vernal grass, Yorkshire fog, commercial

*See Stapledon and Davies (1930).

timothy, commercial Italian rye-grass and commercial perennial rye-grass with over 90 per cent. panicle shoots in the hay. Grasses like the fine-leaved fescues and rough-stalked meadow grass take an intermediate position with about 70 per cent. panicle shoots. Cocksfoot stands rather lower, the indigenous strains showing decidedly fewer panicles than the commercial. The indigenous cocksfoot on the no-nitrogen plots gives 28 per cent. panicle shoots compared with 15 per cent. for indigenous meadow foxtail on similar plots. The superior leafiness of the indigenous strains compared to the commercial is as noteworthy as in previous experiments. Thus the indigenous perennial rye-grass No. 1412 gives a hay *cum* aftermath consisting of over 50 per cent. leaf, while the leaf contribution of the commercial strain is only about 20 per cent.

The contrast in the case of the cocksfoot and meadow foxtail is equally striking, more particularly on the no-nitrogen plots. The leafiness of the commercial timothy comes closer to that of the indigenous, but the advantage remains unmistakably with the latter. Golden oat grass and Italian rye-grass produce hay *cum* aftermath of a decidedly stemmy nature.

YIELD OF THE VARIOUS SPECIES AND STRAINS COMPARED.

The Penglais Field (see Table VIII) was in a much higher state of fertility than the Pond Field (see Table IX) and this is reflected in the hay *cum* aftermath yields from the two fields. It is interesting to note that the gap between the two fields is just as great when nitrogen has been applied to plots on both as when this fertilizer has been withheld.

On the no-nitrogen plots, timothy and meadow foxtail have suffered most from the lack of fertility on Pond Field, while the indigenous cocksfoot and New Zealand cocksfoot have been least affected. The only species (of those where direct comparisons are possible) which under nitrogen have yielded as well on Pond Field as on Penglais under similar treatment have been Italian rye-grass—pedigree and commercial strains, and timothy—commercial strain only. On the field of low fertility, nitrogen has actually increased the yield of these three strains practically three times.

Ample addition of artificial manures is thus seen not to be sufficient to create complete fertility, but it is of interest to note that the species react differentially to induced fertility of this sort, and the reaction of Italian rye-grass here noted is in keeping with its well-known behaviour on sewage farms. Perennial rye-grass even with the addition of nitrogen on Pond Field (first harvest year) is outyielded not only by Italian rye-grass, but also by meadow fescue. On Penglais with nitrogen perennial rye-grass is the most heavily yielding species, and without nitrogen it is only exceeded in yield by golden oat grass and commercial cocksfoot.

When the yields given by the present trials are compared with those obtained in previous experiments* several interesting points are brought into prominence. There is no absolute regularity in the relative yielding ability of the different species and strains—not even when only plots which have developed maximum stands are considered. Certain species and strains are potentially heavy yielding—that is all that can be said with certainty. The most important and the most definite fact that emerges is that the indigenous strain of red fescue must be classed with the potentially heavy yielding hay *cum* aftermath strains. Even in the first harvest year under nitrogen (Pond Field) this strain ranks fourth in the

*Stapledon *et al.* (1922) and Stapledon and Davies (1930).

scale of yield (excluding chicory), and is only surpassed by indigenous and New Zealand cocksfoot in the second harvest year. While in an earlier experiment, on the basis of the sum of four harvest years, it was third in the scale of yield—indigenous tall fescue and indigenous timothy taking first and second places respectively. Yorkshire fog (only tested on Pond Field) must evidently also rank as a potentially high yielding species.

Of the high yielding species it would seem probable (on the basis of hay *cum* aftermath) that indigenous timothy (hay type) and tall fescue are capable of greater productivity than any other strains that have come under test. In the present trials, however, indigenous timothy (although much superior to the commercial strain) has made a relatively poor showing. Golden oat grass and tall oat grass, although both high yielding, especially in the first harvest year, have not attained to first position in any of our experiments. Perennial rye-grass, Italian rye-grass and cocksfoot have all in one series of experiments or another taken first place in yield. Italian rye-grass is of course only capable of doing so in the first harvest year. The commercial strains of perennial rye-grass and cocksfoot usually yield most heavily in the first harvest year. The indigenous strains most frequently do so in subsequent harvest years, although the differences are not usually pronounced until the third or fourth harvest year. In the present trials on Penglais, even in the first harvest year, the indigenous rye-grasses have yielded practically as well as the commercial, and under nitrogen the indigenous cocksfoot has outyielded the commercial. On Pond Field, the commercial perennial rye-grass has outyielded the indigenous by a considerable margin in the first harvest year, and by a slight margin in the second harvest year. The indigenous cocksfoot on this field under nitrogen yielded slightly less than the commercial in the first harvest year, and slightly more in the second. On the no-nitrogen plots the advantage was with the commercial strain in both harvest years, although only to a very slight extent in the second year.

Meadow fescue is capable of very high hay *cum* aftermath yields: thus on Pond Field in the first harvest year it did very decidedly better than any of the strains of perennial rye-grass, cocksfoot or timothy. It has not, however, taken first place in any of our experiments.

Yorkshire fog has hardly the potential yielding capacity of the rye-grasses, timothy, cocksfoot, tall fescue, meadow fescue or red fescue, but ranks decidedly above meadow foxtail, which grass cannot be classed with the potentially high yielding species. Crested dogstail, sweet vernal grass, rough-stalked meadow grass and brown top are all low yielding species. Crested dogstail has, however, shown itself capable of relatively high yields compared even to high yielding species subsequent to the second harvest year. Thus in one of our earlier experiments, it was as productive as cocksfoot in the third and fourth harvest years. In the trial under review brown top (Pond Field) in the second harvest year was actually outyielding the rye-grasses. It is of interest to note that under nitrogenous manuring, chicory was one of the highest yielding species.

The foregoing discussion should tend to emphasise the fact that too much reliance should never be placed on the results obtained from any particular yield trial. The value of a grass is a function not only of its yielding ability but equally of all those other important properties that are here under review. Yield is perhaps the least constant property of a grass. Leafiness, stem-shoot : leaf-shoot ratio, and time of flowering, all of great importance in assessing the hay *cum* aftermath value of a species or strain, are to be regarded as more constant characteristics —relatively as between species and strain—than yield.

Ingress of Unsown Species.

Before considering the pasture yields in detail and with a view to a better understanding of the relative position taken by the various species and strains, it will be desirable to discuss certain matters which have a more or less direct bearing upon the yield of the pure grass as such. The points to be considered are (a) ingress of unsown species excluding wild white clover ; (b) ingress of wild white clover, and (c) the persistency of the several strains. In this section we will deal with unsown species other than wild white clover.

Generalized data relative to unsown species are presented in Table XI. The chief unsown species to make a considerable and more or less rapid entry were rough-stalked meadow grass, bent grass, *Poa annua* and Yorkshire fog, with mouse-ear chick-weed, cat's-ear and daisies. The figures indicate the rapidity with which species propense to a particular field gain entry and the success with which they compete with what is sown. This is in keeping with previous results and constitutes a difficult problem in connection with pure plot trials as for that matter it does relative to establishing prepared swards under ordinary farm conditions.

It must be pointed out that the percentages given are based on separations of the herbage (yield percentages) and that by far the largest bulk of this "weed" herbage was gramineous (predominantly rough-stalked meadow grass, bent and Yorkshire fog). Consequently it is perhaps not surprising to find that on the average nitrogen has done nothing to retard the ingress or the spread of such species. On the basis of the three trials (commercial and indigenous strains) and all the harvest years the unsown species contributed 24.8 per cent. on both the with- and without-nitrogen plots.

Although the unsown species on the average do not gain entry more quickly on the plots sown with commercial strains than on those sown with indigenous strains they soon become decidedly more abundant on the former plots. The difference becomes very pronounced in the third and fourth harvest years (Penglais). Thus during these years the unsown species gave averages of 35 per cent. to 39 per cent. on the indigenous plots, and 52 per cent. to 65 per cent. on the commercial plots. This difference is of course a function of the altogether greater persistency of the indigenous strains than of the commercial—the former strains being in stronger and better sustained competition with the volunteer species.

The behaviour of the individual species and strains in relation to unsown species deserves notice. The necessary data are set out in Table XII.

The most successful strains in combating unsown volunteers and in maintaining a relatively pure (single strain) herbage are seen to be—in order of their success—indigenous cocksfoot (No. 1163) and indigenous red fescue at probably the same level, followed by indigenous meadow foxtail and indigenous perennial rye-grass (No. 1412). These are the four strains which, as will be shown in a subsequent section, are also the most persistent. The least persistent strains are golden oat grass, Italian rye-grass, commercial timothy and commercial meadow foxtail—strains which have given place to volunteers by the third harvest year to an extent of from 56 per cent. to over 80 per cent. It would seem to follow that successful strains like cocksfoot and indigenous red fescue are to be ranked as decidedly aggressive, and this must be taken into account when such strains are employed in seeds mixtures. This matter will be dealt with further at a later stage. The fact that even in the first harvest year commercial timothy is only contributing 55 per cent. to the herbage of its plot is very significant when one takes into account the behaviour of this species in seeds mixtures. It does not stand grazing and it

TABLE XI.—*A comparison of the percentage of weeds* in the pasture yields for the various harvest years for each experiment, and averaged for indigenous, commercial, and all grasses.*

Field	Category.	Harvest years. 1† Nitrogen.	1† Control.	2 Nitrogen.	2 Control.	3 Nitrogen.	3 Control.	4 Nitrogen.	4 Control.	Average Nitrogen.	Average Control.
Penglaise	Indigenous	14	17	30	26	39	37	35	36	30	29
	Commercial	20	28	47	35	61	52	65	61	48	44
	All grasses	17	23	38	30	49	44	50	49	39	37
Pond.	Indigenous	26	30	22	23	—	—	—	—	24	27
	Commercial	27	28	24	26	—	—	—	—	26	27
	All grasses	30	32	24	24	—	—	—	—	27	28
Cwm.	Indigenous	10	10	—	—	—	—	—	—	10	10
	Commercial	10	11	—	—	—	—	—	—	11	11
	All grasses.	15	11	—	—	—	—	—	—	15	11

* By " weeds" are here understood unsown species other than wild white clover. The chief species are rough-stalked meadow grass, *Poa annua*, bent and Yorkshire fog, with mouse-ear chickweed, cat's-ear and daisy.

† Including traces of wild white clover on Penglais in the first harvest year only.

TABLE XII.—*To show the percentage of weeds, exclusive of wild white clover, in the herbage of the total pasture yields for each harvest year of every species and strain in the Penglais trial.*

Species and strain.	Harvest years.							
	1		2		3		4*	
	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.
Perennial rye-grass: indigenous 1412 ..	6	11	17	17	22	24	34	42
,, indigenous 1413 ..	11	18	33	27	43	35	—	—
,, Jædersk	21	31	35	28	48	40	—	—
,, commercial ..	6	16	30	20	53	35	69	63
Italian rye-grass: pedigree ..	10	15	56	43	65	63	—	—
commercial	16	15	56	47	73	63	—	—
Cocksfoot: indigenous 1163 ..	8	6	12	12	18	20	26	28
,, 1640 ..	14	8	22	17	27	26	—	—
New Zealand ..	10	24	26	21	35	36	—	—
commercial ..	6	5	30	27	44	41	49	51
Timothy indigenous 310 ..	20	26	38	28	54	45	55	53
,, 309 ..	24	34	54	46	71	66	—	—
Grinstad	33	45	60	48	69	65	—	—
commercial ..	45	45	64	46	76	71	81	78
Meadow foxtail: indigenous ..	8	21	23	25	30	32	35	30
commercial ..	13	37	55	33	67	56	67	63
Fine-leaved fescue: indigenous	21	17	17	17	18	19	27	26
Chewing's	22	30	34	21	42	32	58	54
Golden oat grass	25	34	68	43	82	70	—	—

*Only selected plots sampled in the fourth year.

does not stand competition. In marked contrast is the very decided purity of the indigenous cocksfoot and indigenous perennial rye-grass in the first harvest year.

The contrast between the successful indigenous strains and their commercial counterparts in the fourth harvest year is peculiarly striking and of profound economic significance. The most arresting contrast, however, is that between commercial timothy (80 per cent. unsown volunteer species) and indigenous (54 per cent. unsown volunteer species). The importance of the latter—a pasture strain—will be made apparent in a subsequent section.

INGRESS OF WILD WHITE CLOVER.

Wild white clover was sown on Cwm Field with each of the species and strains. It was not sown on Penglais or Pond Field. All the fields on the Farm are decidedly propense to the local strain of wild white clover which usually makes a considerable and early volunteer entry. The importance of wild white clover can hardly be over-estimated in relation to pasture efficiency and in relation to trials such as we are considering where, *inter alia*, we are concerned with the effect of nitrogen on pasture yield. White clover is both protein- and calcium-efficient, decidedly in

excess of the grasses. The presence of white clover would seem to react favourably on the yielding ability of the grass with which it is associated. This important aspect of the " white clover problem " has been brought into further prominence by trials recently reported upon by Williams.* In excess it is perhaps to be supposed, however, that white clover may be in competition with the grass and possibly tend to reduce the thickness of the grass stand. These are points demanding further and critical *ad hoc* research and concerning which the data under discussion do not permit of a definite pronouncement.

A much-debated and very important matter is the influence of nitrogen as such on the persistency and productivity of white clover as such. This is a complex question depending upon the interaction of a great number of physiological processes. Only one interaction can be considered here. Nitrogen, by greatly favouring grass growth, creates more shading on the with-nitrogen plots. White clover is a light-demander.† The extent of the differential shading will be a function of the rest period allowed between each grazing; and of the rapidity of growth of each grass strain as such. Whatever the length of the rest period the shading will, however, be greater on the with- than on the without-nitrogen plots, provided always the same rest period has been allowed to each. Such has been the case in connection with the present trials, and on the whole the growth made during the rest period—a month—has been considerable; greater than would have been the case on a well-managed and properly grazed pasture. Greater, that is to say, in the case of all the strains capable of considerable productivity. The results here to be discussed must then be considered as such and merely as proper to the particular experiments under discussion. They are but a part of the extensive evidence which is being accumulated at the Station on the all-important " clover problem." From the practical point of view these results are, however, of great value—for pastures are very frequently undergrazed. The results also throw important light on the complexity of the issues involved when it is desired to decide precisely as to the correct duration at which to aim in connection with a system of intensive grazing. In practice it perhaps does not matter whether nitrogen exerts only an indirect influence on white clover, or whether this influence is both direct and indirect.‡ The first point to be settled is whether an influence is in fact shown, and, if so, under what conditions the influence is most pronounced.§

Generalized and average results obtained from the several trials are set out in Table XIII (data in terms of the actual yields of wild white clover). The most complete and important data are those from Penglais Field. The falling off in the yield of wild white clover in the third and fourth harvest years is noteworthy. This is probably in large measure due to the great increase in the multi-tillering rough-stalked meadow grass and bent grass during these years. The extent of the decrease in white clover in the fourth year is, however, not as great as that implied by the figures. The fourth year data were obtained from selected strains only,

*See Williams (1932).

†See Bates (1929).

‡It may, moreover, with justice be remarked that in proportion as our knowledge of physiological processes advances, we find that we have to assign an ever-increasing importance to pre-disposing influences.

§Let it be once more emphasised that white clover is richer in both protein and calcium than the grasses, and that it is itself a purveyor of nitrogen. So that if under a particular system of management nitrogen does reduce the white clover, the extra grass production must be sufficient to make good what the clover would have provided in nutrients—while in the interest of maintaining the sward at a high level, what the clover would have provided in soil fertility must also be made good.

TABLE XIII.—*To show the yields of wild white clover derived from the grass plots and grouped as* (1) *the average for the indigenous grasses*; (2) *the average for the commercial grasses*; (3) *the average for all grass plots in the trial, and* (4) *the relation of the sum yield of the various harvest years for nitrogen to that of control with control at* 100. *The clover was unsown in the Penglais and Pond Fields, but was sown in the Cwm Field. Yields in lb. of air-dry fodder per* 1/100*th acre plot.*

Field.	Category.	Harvest years. 1 Nitrogen.	1 Control.	2 Nitrogen.	2 Control.	3 Nitrogen.	3 Control.	4 Nitrogen.	4 Control.	Relation of sum yield of nitrogen to control with control at 100.
Penglais.* pasture.	Indigenous	—	—	6.5	20.2	3.8	10.5	1.7	5.4	33
	Commercial	—	—	9.8	20.3	7.2	11.4	4.1	5.2	57
	All grasses	—	—	8.7	21.8	5.5	11.6	2.9	5.3	44
Pond, pasture.	Indigenous	2.6	5.4	1.4	4.1	—	—	—	—	42
	Commercial	2.6	6.4	2.3	4.2	—	—	—	—	46
	All grasses	2.3	5.1	2.3	4.6	—	—	—	—	47
Pond, hay and aftermath	Indigenous	1.0	2.5	0.9	3.6	—	—	—	—	31
	Commercial	1.3	2.3	0.8	3.9	—	—	—	—	34
	All grasses	1.0	1.8	0.7	3.1	—	—	—	—	35
Cwm, pasture.	Indigenous	5.3	8.2	—	—	—	—	—	—	65
	Commercial	5.7	8.8	—	—	—	—	—	—	65
	All grasses	4.6	11.0	—	—	—	—	—	—	42

*The quantity of clover was not appreciable in the first harvest year on Penglais and it was grouped with the weeds.

namely, from the most successful grass strains—from plots in fact upon which wild white clover had not been able to make maximum ingress. The decrease in clover yield may also be due to the fact that phosphatic manures were not applied after the pre-sowing foundation. The fact remains, however, that the yield of wild white clover on Penglais in the second and third years was remarkably high. Actually on the average of all the without-nitrogen plots the volunteer wild white clover contributed about 30 per cent. to the yield of grass *cum* clover in the aggregate of the pasturage of the second year, and about 29 per cent. in the aggregate of the third year. This, the extent to which volunteer wild white clover can—and for that matter frequently in ordinary farm practice does*—contribute to the pasturage taken by animals from swards, is a fact that is probably not sufficiently appreciated. And what this must necessarily mean to the nutritive value of the ration is evident not only when chemical analyses of grasses and clovers† are compared, but also from the results of grazing experiments such as those which have been reported upon by Roberts‡ and those which form the subject of a separate article in this *Bulletin*.§

*In our own trials conducted on prepared and permanent swards wild white clover on certain fields has contributed 26 per cent. to the sum of the eatables throughout the season. See Stapledon and Thomas (1930).

†See Williams and Evans (1932).

‡See Roberts (1932).

§See p. 95.

The figures in the last column of Table XIII are those, however, upon which emphasis needs chiefly to be laid. These figures leave no doubt that there has been a very decided depression of wild white clover yield on the with-nitrogen plots. This depression has shown itself on the three fields alike, and alike on the plots sown with commercial and indigenous strains of grasses. The figures for the second year on Penglais are the most striking, for here the clover yields on the control plots were very high, and, despite the depression, the yields on the nitrogen plots were also relatively high. The result then showed itself on an unmistakably clovery sward and in an unmistakable manner. We can, therefore, assert that nitrogen applied to a clovery sward when the rest period during the grazing season is one of a month definitely and very materially decreases the clover yield throughout the grazing season. We can as a matter of fact go further than this and assert that it does so even on those plots (representing non-luxuriant strains) where the growth of grass *qua* grass during the monthly periods has not been tall or considerable.

We will now consider the evidence in relation to individual species and strains of grass. The most interesting and certainly the most concise evidence is that given by counts which were made (on lifted turfs) at the end of each experiment. The data are set out for Penglais and Pond Fields* separately in Tables XIV and XV. In these tables the counts made relative to the grasses are also shown—these latter data will, however, be dealt with presently.

In the present connection the Penglais data (Table XIV) are the most reliable and interesting. We have the accumulated influence of four years of treatment—phosphatic and potassic manures with nitrogen and without nitrogen. The first point to be noted is that on both the with- and without-nitrogen plots the wild white clover is decidedly more plentiful in association with commercial than with indigenous strains ; that is to say, with the strains that have persisted least well and which have the least number of tillers in competition with the volunteering white clover. On average figures (commercial and indigenous) the ratio white clover with nitrogen : white clover without nitrogen is 100 : 149. White clover is seen to be most abundant on the commercial meadow foxtail and golden oat grass no-nitrogen plots. This latter grass was quite incapable of persisting under the regularized system of grazing, and in the second and third harvest years was exercising but little shading or competitive effect even on the nitrogen plot, while on the commercial meadow foxtail plot the crop was scanty and the shading relatively slight throughout the experiment. The nitrogen : no-nitrogen ratio for the wild white clover on the average of these two strains was, however, 100 : 170. No grass strains would have more consistently outshaded or out-crowded the wild white clover than indigenous cocksfoot and indigenous perennial rye-grass. It will be noted that the wild white clover was decidedly less plentiful on these plots (nitrogen and no-nitrogen) than on the corresponding plots of commercial meadow foxtail and golden oat grass. The ratio (expressed in the same terms as above) was, however, 100 : 180. Thus the white clover ratio is substantially the same as between fairly dense herbage (the control cocksfoot and rye-grass) and very dense herbage (the nitrogen equivalents) on the one hand, and scant herbage (the control golden oat and commercial meadow foxtail) and somewhat less scant herbage (the nitrogen equivalents) on the other hand. The herbage would not have been quite as scant on these golden oat, commercial foxtail plots as the yield figures indicate (see subsequent section on "Yield") because, of course, bent and other

*It was not found possible to make end-stage counts on Cwm Field.

TABLE XIV.—*To show the number of tillers, under pasture, of wild white clover and of the sown species per 2½ square feet present at the end of the Penglais trial. Also the relation of indigenous grasses to commercial, with commercial at* 100, *and the relation of nitrogen to control, with control at* 100. *The date of sowing was May,* 1926, *and counts were made in May,* 1931.

Species and strain.	Nitrogen.				Control.		
	No. of clover tillers.*	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.	Relation of nitrogen grass tillers to control with control at 100.	No. of clover tillers.	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.
Perennial rye-grass : indigenous ..	121	844	281	124	136	679	284
,, commercial ..	143	300		126	139	239	
Italian rye-grass : pedigree ..	171	39	144	115	147	34	58
,, commercial ..	142	27		46	150	59	
Cocksfoot : indigenous	43	794	483	114	106	699	422
New Zealand	47	364		141	110	257	
commercial	167	164		99	226	166	
Timothy : indigenous	142	357	637	146	211	245	350
commercial	131	56		80	195	70	
Meadow foxtail : indigenous ..	142	772	742	86	226	900	570
,, commercial ..	207	104		66	305	158	
Fine-leaved fescue : indigenous ..	54	4024	134	114	140	3543	121
,, commercial ..	48	3017		103	98	2941	
Golden oat grass : commercial ..	135	7		100	260	7	
Average for indigenous strains† ..	100	1358	—	112	164	1213	—
Average for commercial strains ..	139	728	—	102	193	715	—

*In the case of white clover, a " tiller " represented a piece of stolon having functional leaves and rootlets.
†Italian rye-grass, New Zealand cocksfoot and golden oat grass not included.

grasses would have come in to a large extent. The point must, however, be made that even on the nitrogen plots of these " scant " grasses the amount of herbage (and of shading) would not have been nearly as much as would occur on a normal pasture managed normally on the intensive system. The comparative constancy of the ratio is interesting, and if we did not know that shading does reduce wild white clover, we might be led to regard this very constancy as suggesting that shading was not an important factor. It may come nearer the truth, however, to suppose that shading *qua* shading is so important that a little more or less may exert a considerable influence even when in both cases (the " more " and the " less ") the shading as such is very slight.

That shading does in fact have a very real influence is indicated by the white clover content of certain plots in particular. Thus on the no-nitrogen plots the highest yielding strains were the two red fescues and indigenous cocksfoot, and the white clover content (at the end of the experiment) was at its lowest under Chewing's fescue and indigenous cocksfoot ; it was higher under indigenous red fescue, but below the average for all species and strains. On the control plots wild white clover was most abundant on the scant-yielding golden oat grass and commercial meadow foxtail plots. Under nitrogen the heaviest yielding plots were the two red fescues, and indigenous and New Zealand cocksfoot, and on these four plots the wild white clover contribution (at the end of the experiment) was exceptionally low—48 " tillers " per unit of area, compared to the average of 120 for the nitrogen plots of all species and strains.

The data from Pond Field (Table XV) bear out those from Penglais as showing that on the average of all species and strains there is a decided preponderance of wild white clover on the no-nitrogen plots, the ratio being 100 : 136.

These data, however, are the outcome of only two years' treatment, and although wild white clover came in quickly on the field from which they were obtained, it had not achieved a strong hold on the sward in the second harvest year (cf. Table XIII, and also note that the " tillers " per unit of area were less than on Penglais). On this account too much reliance should not be placed on the results for individual plots. It may, however, be of possible significance that in association with four strains of grasses out of nineteen the greatest amount of wild white clover actually occurred on the with-nitrogen plots. The difference in favour of the nitrogen plots was, however, only of an appreciable magnitude in the case of the crested dogstail and indigenous timothy plots ; the ratio (with nitrogen : without nitrogen) on the average of these plots being 100 : 79. The crested dogstail gave very low yields ; it was the lowest yielding grass in the Pond Field experiment, and therefore would not have outshaded the white clover or competed with it to any appreciable extent even on the nitrogen plot. The indigenous timothy, on the other hand, was one of the heaviest yielding strains on the nitrogen plots in this experiment, and although a comparatively short growing strain there would have been decided differential shading on the nitrogen plot compared to the no-nitrogen.

As on Penglais, there was more white clover associated with commercial than with indigenous strains, and again, indigenous cocksfoot and indigenous red fescue show themselves able to resist wild white clover to a marked degree.

The influence of two years of hay and aftermath on white clover (" tillers " per unit of area) can be seen by reference to Table XVI in which these data are presented for Pond Field. Taking the two harvest years together the effect of nitrogen has been to increase the hay *cum* aftermath yield by more than double—consequently the extra shading on the nitrogen- as compared to the no-nitrogen plots was here very considerable. The ratio for the clover on the nitrogen plots

compared to the no-nitrogen is 100 : 359, which is a far greater contrast than that shown on the pasture plots. The pasture ratio for the same field was 100 : 136.

The average number of " tillers " of white clover on the nitrogen plots of hay *cum* aftermath was 41, while on the nitrogen pasture plots it was 85. Somewhat unexpectedly, however, there are rather more wild white clover tillers per unit of area on the no-nitrogen hay *cum* aftermath plots than on the no-nitrogen pasture plots—the figures respectively are 147 and 116. It is to be remarked, however, in this connection that the hay *cum* aftermath yields on the no-nitrogen plots were very poor.

Reverting to the nitrogen hay *cum* aftermath plots, the three strains of cocksfoot and indigenous red fescue were amongst the heaviest yielding in hay *cum* aftermath, and under these strains there was very little white clover. Crested dogstail and rough-stalked meadow grass gave the poorest hay *cum* aftermath yields, and on these plots wild white clover was relatively plentiful. A partial exception to this relationship of greater crop and greater shading less wild white clover is given by indigenous meadow foxtail which cropped relatively well (though decidedly less well than cocksfoot) and was associated with as much wild white clover as crested dogstail for instance.

The hay *cum* aftermath evidence as a whole, however, shows very definitely that shading *qua* shading is a factor that tends greatly to reduce white clover (note also on the control plots the poor white clover content under cocksfoot). We have seen furthermore that in hay *cum* aftermath the addition of nitrogen greatly exaggerates the shading effect with a correspondingly adverse influence on the white clover. It would not be safe, however, to assume on this account that shading as such is the only effect—and this an indirect effect—for which nitrogen has been responsible.

The evidence relative to reduction of wild white clover in pasture (on the basis of rests of one month) strongly suggests that shading has much to do with it, but also indicates that competition, irrespective of shading, is probably also of decided significance. The evidence from these experiments, is, however, in some respects a little conflicting and in any event is not nearly sufficient upon which to attempt anything of the nature of a final differentiation as between the " directness " and " indirectness " of the action of nitrogen. From the practical point of view, in the last resort, the " directness " or " indirectness " of an effect matters very little, except in so far as a complete knowledge of the phenomenon in all its inwardness may assist the farmer to counter an adverse effect. This will be of little use, however, unless it points the way to doing so by means which are economic. Sufficient, therefore, to say that under a system of management conducted on prepared swards upon which wild white clover was capable of making a considerable volunteer entry (*e.g.* Penglais Field in particular) and when a month's rest was allowed between each grazing, wild white clover yielded less highly and was present at the end of the experiment in very appreciably less quantity on the nitrogen- than on the no-nitrogen plots. The evidence as a whole (despite the exceptions referred to) also showed that this state of affairs manifested itself equally on plots where even under nitrogen the month-old herbage was at all times scant.

Persistency of the Sown Species and Strains.

The data for considering this important question have been set out in Tables XIV, XV, and XVI, to which reference must again be made. All the data in these tables have been based on accurate counts on lifted turfs at the end of each experiment (counts were not, however, made on Cwm Field), and are given

TABLE XV.—*To show the number of tillers, under pasture, of wild white clover and of the sown species per 2½ square feet present at the end of the Pond Field trial. Also the relation of indigenous grasses to commercial with commercial at* 100, *and the relation of nitrogen to control with control at* 100. *The date of sowing was May,* 1928, *and counts were made in October,* 1930.

Species and Strain.	Nitrogen.				Control.		
	No. of clover tillers.	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.	Relation of nitrogen grass tillers to control with control at 100.	No. of clover tillers.	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.
Perennial rye-grass : indigenous ..	60	1025	227	179	170	572	189
,, N.Z.	122	351		150	159	234	
,, commercial ..	131	451		149	170	302	
Italian rye-grass	130	247		134	179	185	
Cocksfoot : indigenous	33	575	143	86	64	672	167
,, New Zealand	10	478		137	96	350	
,, commercial	55	402		100	76	403	
Timothy : indigenous	118	266	165	85	81	312	163
,, commercial	102	161		84	122	192	
Meadow foxtail : indigenous	94	412	710	114	107	361	463
,, commercial ..	123	58		74	129	78	
Fine-leaved fescue : indigenous ..	38	1776	188	134	90	1328	224
,, commercial ..	99	949		159	156	595	
Meadow fescue	102	177		107	169	165	
Crested dogstail	218	159		144	186	111	
Rough-stalked meadow grass	151	984		144	126	684	
Sweet vernal	176	516		164	185	315	
Yorkshire fog	107	685		80	250	858	
Tall fescue	136	293		145	131	202	
Average for indigenous strains ..	69	811	201	125	102	649	200
Average for commercial strains ..	102	404		129	131	314	

in terms of tillers per unit of area. Reference should first be made to Table XV, which shows the state of affairs at the end of two harvest years (Pond Field).

Results at the end of the second harvest year. Even at the end of a second year the indigenous strains (average of all strains) will be seen to be giving twice as many tillers per area as the commercial, and this alike on the with- and without-nitrogen plots. The difference in favour of the indigenous strain is particularly striking in the case of perennial rye-grass, timothy, meadow foxtail and red fescue. Nitrogen has undoubtedly and quite strikingly increased the number of tillers per area. All these results are in strict accord with those given by earlier trials. The excessively high tillering capacity of red fescue is to be noted, and very high tillering are rough-stalked meadow grass, indigenous perennial rye-grass, Yorkshire fog, indigenous cocksfoot, and sweet vernal grass. Relatively low tillering are crested dogstail, Italian rye-grass, commercial timothy and commercial meadow fescue.

These data obtained after two years pasture should be compared with counts made after two years' hay and aftermath (see Table XVI). It will be noted that on average figures there are decidedly more tillers on the pasture plots than on the hay *cum* aftermath plots. In the majority of our previous experiments the case has been otherwise. This difference is of considerable interest because in the present trials the defoliation has been by sheep and not by shears or the mowing machine. Moreover, the rest period was here a month, and ample and complete recuperation was assured between each grazing. These results are in keeping with those previously obtained on cocksfoot where cutting at 6 in. was compared to cutting to ground level and to hay and aftermath.* In that case, despite the fact that the rest period was only three weeks, the tillers were quite as numerous under 6 in. cutting as under hay and aftermath.

Under hay *cum* aftermath it will be seen that again the advantage is (1) quite decidedly with the indigenous strains, and (2) with the plots receiving nitrogen. In respect of strain, however, the advantage is most marked under pasture conditions, which is what would be expected. In respect of nitrogen the advantage is most pronounced under hay *cum* aftermath in the case of the indigenous strains, while the commercial strains in regard to this matter of tillers have responded equally to nitrogen under both hay and pasture conditions, and this too is in keeping with the yielding and other peculiarities of the contrasting strains. Those species which are high tillering under pasture conditions are also high tillering under hay *cum* aftermath conditions. A careful study of Tables XV and XVI goes to confirm the important fact (to which all our experiments have pointed) that tillering capacity is a quantitative characteristic which is very constant regarded as a contrasting feature between different species and strains. The marked difference between commercial and indigenous strains even as soon as the second harvest year is well shown in Plate I, fig. 2, and Plate, II, fig. 1 ; the photographs were taken respectively on the commercial and indigenous plots of cocksfoot (Penglais Field).

Results at the end of four harvest years. From the point of view of persistency the data from Penglais (Table XIV) are to be regarded as the most important as yet obtained at the Station. Here we have accurate counts made on replicated plots (with and without nitrogen) at the end of four years of pasture treatment. We see that in this important matter the advantage is with the indigenous strain

*See Stapledon and Milton (1930).

TABLE XVI.—*To show the number of tillers, under hay and aftermath, of wild white clover and of sown species per 2½ square feet present at the end of the Pond Field trial. Also the relation of indigenous grasses to commercial with commercial at* 100, *and the relation of nitrogen to control with control at* 100. *The date of sowing was May,* 1928, *and the counts were made in October,* 1930.

Species and strain.	Nitrogen.				Control.		
	No. of clover tillers.	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.	Relation of nitrogen grass tillers to control with control at 100.	No. of clover tillers.	No. of grass tillers.	Relation of indigenous grass tillers to commercial with commercial at 100.
Perennial rye-grass : indigenous ..	48	398	109	83	170	482	141
,, N.Z.	17	231		102	138	227	
,, commercial ..	51	367		107	159	343	
Italian rye-grass	52	192		134	115	143	
Cocksfoot : indigenous	12	355	187	120	47	296	219
,, New Zealand	1	183		129	54	142	
,, commercial	11	190		141	45	135	
Timothy : indigenous	29	147	98	263	125	56	79
,, commercial	75	151		213	183	71	
Meadow foxtail : indigenous ..	73	104	180	117	217	89	148
,, commercial ..	30	58		97	242	60	
Fine-leaved fescue : indigenous ..	20	1534	392	179	108	857	124
,, commercial ..	61	391*		57	175	691	
Meadow fescue	70	171		138	167	124	
Crested dogstail	64	59		738	227	8*	
Rough-stalked meadow grass	91	402		163	179	246	
Average for indigenous strains ..	36	508	154	143	133	356	137
Average for commercial strains ..	46	331		127	161	260	

*Very weedy plots.

in respect of each species, and this to a really remarkable extent in the case of meadow foxtail, timothy and cocksfoot, where we have the indigenous strain three to seven times as persistent as the commercial, while indigenous perennial rye-grass is nearly three times as persistent as the commercial strain.

In this trial indigenous cocksfoot has gone into the fifth harvest year with practically as many tillers as indigenous rye-grass. In previous trials the advantage had been quite decidedly with the rye-grass. In this case the rest period was, however, one month (instead of three weeks) and the defoliation by sheep—this less drastic treatment being relatively much in favour of cocksfoot. The relatively good persistency of the indigenous timothy is in accord with earlier trials, and is of particular interest having regard to the punishing extent to which this highly palatable strain had been grazed all through the experiment, and having regard to the very poor showing of commercial timothy. The excellent persistency of both the red fescues is noteworthy, and equally striking is the manner in which golden oat grass has died out. Golden oat grass actually gives fewer tillers per unit than Italian rye-grass at the end of four years. Golden oat grass is thus quite incapable of persisting under even as lenient pasture conditions as those under which the experiment was conducted. Under hay conditions it is however a grass that has been shown to persist remarkably well.*

The Pond Field data (Table XV) showed that at the end of the second harvest year the plots with nitrogen (both commercial and indigenous strains) had very appreciably more tillers (about 27 per cent.) per unit of area than the no-nitrogen plots. Similar results had been obtained in earlier trials on drills and single spaced plants at the end of a first harvest year.† The counts immediately under consideration (Table XIV), however, show that by a fifth harvest year nitrogen, although applied in incremental doses in each harvest year, had not helped the final persistency of the individual strains to anything like the same extent as was apparent at the end of a second year. The non-persistent commercial strains (average of all species) had not been appreciably helped, while the indigenous strains (average of all species) only showed an advantage of 12 per cent. It is perhaps significant, however, that both indigenous and commercial rye-grass (a species which is undoubtedly a " high fertility demander ") showed an increase of 24 per cent. of tillers on the nitrogen plot over the no-nitrogen. Indigenous timothy showed to the greatest advantage with a gain of 46 per cent.

Persistency from year to year. The difficulty of making really accurate plant and tiller counts *in situ* renders it no easy matter to compare persistency from year to year unless the plots are large enough to permit of lifting sample turfs each year.

This was not possible in the case of the present trials. Plant counts can, however, be made on the ground with very fair accuracy in the first harvest year except in the case of such a highly tillering plant as red fescue. While if great care is exercised and much time devoted to the work, tillers can be counted on the ground from year to year with a high degree of comparative accuracy. Owing to the labour involved, these complete data have only been collected in the case of a few of the more persistent strains in contrast with some of the least persistent. The results of these counts are set out in Table XVII. The counts given for the first harvest year (1927) were made just prior to the application of the first dressing of nitrogen ; these figures are therefore the average of the " with-" and " without nitrogen " plots and stand equally for both.

*Cf. Stapledon and Jenkin (1916).
†See Stapledon and Milton (1930).

Even in the case of indigenous perennial rye-grass, one of the most persistent strains, the number of tillers per area has fallen off very considerably from the third to the end of the fourth harvest year, and quite appreciably from the second to the third year. The number of plants per unit has been substantially maintained. In the case of the commercial strain of perennial rye-grass the number of plants has fallen off very considerably and the greatest drop in tillers has shown itself in the third year.

Cocksfoot is interesting—the indigenous strain has maintained or more than maintained its plant population* but has fallen off in tillers by the end of the fourth year (compared to the second year), though not to the same relative extent as indigenous rye-grass. The commercial cocksfoot has shown a very marked reduction in both plants and tillers.

In this, as in previous trials, the tendency has been not only for the number of tillers to fall off as time goes on, but for the tillers to become smaller, and this even in the case of the most persistent strains.

Plant counts made at the beginning and at the end of the experiment are also set out for commercial timothy, commercial meadow foxtail and golden oat grass, all of which show a highly-pronounced reduction in population per unit of area. This as would be expected is most striking in the utterly non-persistent golden oat grass. Under regularised grazing as here practised golden oat grass, tall oat grass and *Bromus arvensis* die out to a very considerable extent even in the

TABLE XVII. *To show the number of plants and (or) the number of tillers per 2½ square feet in the first and subsequent harvest years. Data for selected individual strains from single plots.* Penglais Field.*

Species and strains.	Treatment.	1927 plants.	1928 tillers.	1929. tillers	Final counts at the end of 4th year.	
					Plants.	Tillers.
Perennial rye-grass: indigenous	Nitrogen.	93	1700	1582	88	865
	Control.		1232	1096	90	786
„ commercial	Nitrogen.	73	863	351	48	300
	Control.		669	247	38	239
Cocksfoot: indigenous ..	Nitrogen.	75	1000	1037	99	845
	Control.		846	563	77	722
„ commercial ..	Nitrogen.	74	440	244	46	164
	Control.		245	244	46	166
Timothy: commercial ..	Nitrogen.	77	—	—	20	—
	Control.		—	—	32	—
Meadow foxtail: commercial..	Nitrogen.	153	—	—	32	—
	Control.		—	—	45	—
Golden oat grass: commercial	Nitrogen.	143	—	—	6	—
	Control.		—	—	6	—

* The figures in Table XIV are averages for replicated plots and frequently for more than one lot. The figures in this table are therefore in no case abstracted from Table XIV.

first harvest year, and are worthless species where intensive grazing is concerned, while under these conditions commercial timothy and commercial meadow foxtail provide an almost negligible amount of fodder after the first year.

*As the result presumably of a certain amount of delayed germination or delayed seedling growth—cf. Stapledon, Davies and Beddows (1927).

The relative persistency of the various strains is in direct relationship to the weediness of the plots—the most persistent strains are the least weedy.

This question of weediness and persistency will be discussed in further detail when considering diminishing pasture yields.

Yields of Hay *cum* Aftermath Compared to Sum of Pasture Cuts.

An interesting feature of all previous experiments has been that the sum of the hay and aftermath cuts has almost invariably considerably outyielded the sum of a system of pasture cuts. The more frequent and the more drastic the cutting the greater the advantage in favour of hay *cum* aftermath. In all our previous trials the defoliation has been accomplished by shears or the garden mowing machine, and even when the rest period has been as long as a month under this system of treatment the ratio hay *cum* aftermath : sum of pasture cuts has varied from about 100 : 60 to 100 : 83.

In the case of the present trials the defoliation has of course been by sheep, and only in a few cases and at particular grazings would the defoliation have been as complete and as drastic as that effected by shears. During some of the growing periods (a month) the conditions were very favourable and the yields very high—the plots on several occasions when due for grazing actually presenting an appearance rather of hay than of pasture. It follows that under the conditions of this experiment the plants were given ample scope for recuperation between each grazing.

There is no necessity to discuss the behaviour of the individual species and strains in detail since practically all have behaved in a manner generally similar. Results are only available for a comparison in the first harvest year and this in respect of Pond Field and Penglais. The essential facts can be presented by means of the ratios hereunder which are based on the average figures for all species and strains. In the reaction under discussion the indigenous and commercial strains have behaved in a similar manner, the ratios for each set of strains being substantially the same :—

	Ratio hay *cum* aftermath : pasture.	
	With nitrogen.	Without nitrogen.
Penglais	100 : 181	100 : 266
Pond Field	100 : 120	100 : 161

Here then in the case of both fields we have ratios vastly different from those obtained in earlier experiments and in favour of the pasture to what at first sight would seem a quite surprising extent. It is probable, however, that the extent of the difference in favour of pasture has been somewhat exaggerated by the system of sampling adopted on the pasture plots. This, it will be remembered, consisted of taking a number of mesh samples before each grazing ; and owing to the smallness of the plots the area of the mesh had necessarily to be small. The appearance of the pasture plots, however, rendered it perfectly apparent that pasture would very substantially outyield hay *cum* aftermath. Even if the pasture yields had been exaggerated to an extent of as much as, or even more than 20 per cent. the significance of the ratios would remain.

It is of considerable interest to note that pasture stands at an even greater advantage to hay *cum* aftermath on Penglais (a field in a highly fertile condition) than on Pond Field (of low fertility). Because, as has been previously shown, hay *cum* aftermath gives a higher reaction to nitrogen than does pasture, the ratios are of course wider (most pronouncedly in favour of pasture) on the without-nitrogen plots.

Since pasture is always very much more leafy than hay *cum* aftermath, the ratio based on leaf yield instead of on total yield is even more in favour of pasture.* The leaf yield ratios for Penglais are :—

Ratio for leafage of hay *cum* aftermath : leafage of pasture.

With-nitrogen.	Without-nitrogen.
100 : 322	100 : 504

In so far as species and strains are concerned, it may be said that on Penglais, without a single exception, and alike on the with- and without-nitrogen plots, the pasture yields were far in excess of the hay *cum* aftermath. On the control plots the pasture leafage was over seven times that of the hay *cum* aftermath leafage in the case of Italian rye-grass and some of the strains of cocksfoot. On Pond Field the only exceptions to pasture outyielding hay *cum* aftermath were indigenous red fescue and tall oat grass, which gave somewhat heavier hay *cum* aftermath yields on the nitrogen plots.

The evidence we have discussed has a two-fold interest. In the first place, it serves to emphasise that the method of grazing adopted in these experiments was decidedly lenient, and all the conclusions that are drawn are of course subject to this essential reservation. In the second place, it is very important to emphasise the fact that an overwhelming proportion of this heavy bulk of pasturage produced was in fact grazed and converted by the sheep consequent upon the method of control adopted.

By adopting such a method it is then possible to produce and to convert an amount of leafage that could never be developed under any normal method of pasture management. To have grown and converted as pasturage over twice† as much leaf as was harvested as hay and aftermath represents a considerable achievement—an achievement which cannot fail to have practical implications. Speaking generally, this leafage at many of the grazings was taken in too advanced a stage to be either of maximum palatability or of maximum nutritive value. But just because the vast majority of the herbage was leaf, it was always of high nutritive value. The amount of nutrients per acre, taken from the highest yielding plots, must have just about approached the maximum of what was possible for the strains concerned.

It must be remembered, however, as shown in a previous section, that this taking of a succession of very heavy pasture " crops " definitely hampers wild white clover development. No attempt will be made in the present paper to hazard an opinion as to the ideal rest period under which to conduct intensive grazing, but it is as well to emphasise the various incompatibilities that call for reconciliation as demonstrated by our evidence. This aspect of the question will, however, be further considered when dealing with leaf yield as such.

Yields of Pasture.

The yield data in respect of pasture are set out in Table XVIII (Penglais ; three harvest years) ; Table XIX (Pond Field ; two harvest years) and Table XX (Cwm Field ; one harvest year). The yield figures are of course for the pure

*Even when cutting is performed with shears, provided the rest period is a long one (*e.g.* about a month), the pasture leafage will usually approximate to, or in the case of some strains slightly outyield, the hay *cum* aftermath leafage. Cf. Stapledon and Davies (1930).

†To have said " over twice as much " rather than " over three times as much " is to have made a very conservative intrepretation of our data, and to have made an unduly generous allowance for any errors due to sampling.

produce of each plot after white clover and other extraneous species have been discarded. The figures represent the sum of the produce given by the several cuts for each of the harvest years.

In considering the yield results it must be remembered that the rest periods were practically of a month's duration. During the first and second harvest years this length of rest permitted of a great deal too much growth, and to have conformed to more normal practice and to have converted the herbage in a more readily palatable condition it should ideally have been reduced to 14 days at the height of the growing season, and especially so on the plots receiving nitrogen. Owing to the method of sampling necessarily adopted it is probable that the actual yields recorded in the tables are somewhat exaggerated. The figures are, however, important as relatives—for the purpose of comparing treatments and strains—and not as absolutes. Since the methods of sampling were the same for all treatments and strains, and replication was ample, the figures are adequate for the comparative purpose in view.

THE FIELDS COMPARED.

As in the case of the hay *cum* aftermath yields, it will be noted that those from Penglais are altogether heavier than those from either Pond Field or Cwm Field. In respect of the first harvest year, both on the with- and without-nitrogen plots the productivity of Penglais shows itself as over twice that of Cwm Field or Pond Field. On the basis of the average of all species and strains, the yields from the control plots on Penglais were higher than those from the with-nitrogen plots on either of the other two fields. These comparisons are of interest as showing the complexity of the factors influencing fertility. Nitrogen in support of phosphatic manures was, however, responsible for a greater relative increase on the "infertile" fields than on the "fertile" field. The increased productivity directly due to added nitrogen was 48 per cent. on Penglais compared to 58 per cent. on Cwm Field and 56 per cent. on Pond Field. Not a single species or strain under pasture either with or without nitrogen has yielded as well on the "infertile" fields as on Penglais (cf. hay *cum* aftermath p. 32).

THE INFLUENCE OF NITROGEN.

As pointed out when considering the hay *cum* aftermath results the proportional increase due to nitrogen is much less on the sum of the pasture cuts than on hay and aftermath. And this despite the fact that the pasture treatment was lenient and the gross yields from pasture heavier than from hay *cum* aftermath.

In the case of hay *cum* aftermath the indigenous strains responded altogether more sumptuously to nitrogen than did the commercial, and this even in the first harvest year. Under pasture conditions in the first harvest year nitrogen reacted very much more beneficially on the indigenous strains than on the commercial on Cwm Field. On Penglais and Pond Fields, however, both commercial and indigenous strains reacted very similarly. In the later harvest years on all fields alike the indigenous strains responded more freely to nitrogen.

Yield data were obtained on a few selected strains in the fourth harvest year on Penglais. These data are embodied in the figures set out in Table XXI. In this table the percentage increase due to nitrogen is given in respect of the indigenous strains of five species respectively in each of the four harvest years. The indigenous strains have been selected because they were the more persistent. Reference to the table shows that the beneficial results of nitrogen declared themselves most strongly in the first and second harvest years and decreased very appreciably in the third

TABLE XVIII.—*To show the pasture yields in lb. of air-dry fodder per 1 100th acre plot for the three harvest years of the Penglais trial and the percentage increase of the nitrogen yield over the control for the sum yield of the three years.*

Species and strain.	Nitrogen.				Control.				Percent. increase of nitrogen over control for sum yield of three years.
	1927	1928	1929	Total	1927	1928	1929	Total.	
Perennial rye-grass : indigenous 1412	132.8	67.4	47.0	247.2	79.8	36.3	32.7	148.8	67
,, ,, 1413	128.4	83.3	44.7	256.4	69.9	55.2	33.2	158.3	67
,, Jædersk	99.8	74.7	39.0	213.5	52.8	41.6	30.6	125.0	71
,, commercial	143.5	60.5	26.9	230.9	78.5	33.6	21.7	133.8	73
Italian-rye-grass : pedigree	111.1	46.0	19.5	176.6	72.4	26.0	13.5	111.9	58
,, commercial	99.1	46.5	16.6	162.2	74.9	24.1	11.1	110.1	49
Cocksfoot : indigenous 1640	96.2	118.1	69.3	283.6	94.9	69.4	47.4	211.7	34
,, ,, 1163	121.9	82.5	59.3	263.7	90.0	47.1	34.3	171.4	54
,, New Zealand	118.2	109.8	50.7	278.7	74.8	55.8	38.3	168.9	65
,, commercial	141.4	47.2	34.2	222.8	109.0	30.7	26.2	165.9	34
Timothy : indigenous 309	97.6	53.1	17.2	167.9	65.2	34.0	16.5	115.7	46
,, ,, 310	112.6	104.6	42.8	260.0	69.5	42.3	25.4	137.2	89
,, Grindstad	78.6	47.7	19.7	146.0	54.8	29.7	15.8	100.3	46
,, commercial	70.7	34.5	12.9	118.1	46.7	29.5	14.5	90.7	30
Meadow foxtail : indigenous	138.7	84.3	55.7	278.7	79.0	42.0	32.5	153.9	82
,, commercial	103.4	28.7	16.1	148.2	52.6	18.5	14.5	85.6	74
Fine-leaved fescue : indigenous 728	123.3	160.9	98.1	382.3	97.8	89.8	50.3	237.9	61
,, Chewing's	123.5	119.6	58.6	301.7	92.3	83.4	52.2	227.9	32
Golden Oat grass	103.9	25.9	6.9	136.7	74.2	28.9	9.8	112.9	21
Average for indigenous strains	118.0	89.0	50.5	257.5	80.0	49.3	31.7	161.0	60
Average for commercial strains	113.0	56.3	27.6	196.9	75.8	36.6	23.4	135.8	45

TABLE XIX.—*To show the pasture yields, in lb. of air-dry fodder per 1/100th acre plot, for the species and strains in the two harvest years of the Pond Field trial. Also the percentage increase of the nitrogen yield over the control for each year. Nitrogen was applied after each grazing in 1929, but was withheld at the mid-season grazings in 1930.*

Species and strain.	No. of strains averaged.	1929. Yield. Nitrogen.	1929. Yield. Control.	1929. Percent. increase of nitrogen over control.	1930* Yield. Nitrogen.	1930* Yield. Control.	1930* Percent. increase of nitrogen over control.
Perennial rye-grass : indigenous	2	51.2	30.1	70	47.0	41.6	13
,, N.Z.	2	67.5	48.9	38	34.0	34.2	—
,, commercial	3	72.7	47.1	54	37.4	34.1	10
Italian rye-grass : pedigree	1	74.0	55.4	34	32.9	18.3	80
,, commercial	2	72.3	54.5	33	35.8	26.7	34
Cocksfoot : indigenous	7	49.2	35.2	40	52.5	41.7	26
,, New Zealand	1	53.2	33.4	59	47.7	34.9	37
,, commercial	8	61.3	34.7	77	46.0	33.0	39
Timothy : indigenous	2	48.4	28.2	72	51.2	37.5	36
,, commercial	3	61.3	31.0	98	40.0	38.5	4
Meadow foxtail : indigenous	2	53.5	27.8	93	50.0	39.9	25
,, commercial	1	43.9	21.7	102	39.1	30.5	28
Fine-leaved fescue : indigenous	1	45.7	24.0	90	58.8	50.3	17
,, Chewing's	1	26.9	20.2	33	37.8	31.8	19
Meadow fescue : commercial	2	62.2	45.6	36	42.3	46.5	—
Crested dogstail : commercial	1	13.7	8.7	58	18.9	15.4	23
Rough-stalked meadow grass : commercial	1	45.4	24.1	88	28.0	31.0	—
Tall oat grass : commercial	1	25.6	7.0	266	†	—	—
Tall fescue : commercial	1	55.3	29.7	86	52.2	41.7	25
Sweet vernal : commercial	1	33.9	31.0	9	34.9	34.3	2
Yorkshire fog : commercial	1	56.5	49.7	14	37.3	34.0	10
Bromus arvensis : : commercial	1	39.8	26.2	52	†	—	—
Montgomery red clover	1	25.2	33.6	—	†	—	—
Chicory	1	37.1	29.4	26	28.9	28.4	2
Average for all grasses	45	50.6	32.4	56	41.2	34.8	18
,, ,, indigenous strains	15	53.7	33.4	61	48.8	38.2	28
,, ,, commercial strains of same species	18	56.5	34.8	62	39.4	32.5	21

* No final spring grazing to complete the grazing year.
† Plots not sampled in the second year, as produce was too slight.

TABLE XX.—*To show the pasture yields, in lb. of air-dry fodder per 1/100th acre plot, for the species and strains in the first harvest year of the Cwm Field trial. Also the percentage increase of nitrogen over control.*

Species and strain.	No. of strains averaged.	Yield of sown species.		Percent. increase of nitrogen over control.
		Nitrogen.	Control.	
Perennial rye-grass : indigenous	2	62.1	36.6	70
„ N.Z.	2	56.1	35.7	57
Italian rye-grass : commercial	1	39.0	37.8	3
Cocksfoot : indigenous	1	62.7	39.5	59
„ New Zealand	1	70.9	40.2	76
„ commercial	1	47.5	48.8	—
Timothy : indigenous	1	45.3	29.7	53
„ commercial	1	53.5	34.8	54
Meadow foxtail : indigenous	1	47.7	28.5	67
„ commercial	1	25.2	18.8	34
Crested dogstail : commercial	1	45.2	25.1	80
Fine-leaved fescue : indigenous	2	67.3	38.1	77
„ Chewing's	1	72.3	37.1	95
Golden oat grass : commercial	1	70.1	31.3	124
Yorkshire fog : commercial	1	69.7	46.6	49
Agrostis : red top : New Zealand ..	1	18.2	26.8	—
„ brown top : New Zealand ..	1	67.1	39.3	71
Bromus arvensis : commercial	1	36.3	21.6	68
Average for all grasses		54.5	34.6	58
Average for indigenous strains		58.5	33.3	76
Average for commercial strains of same species		49.6	34.9	42

and fourth harvest years. On Pond Field (of low fertility) this effect showed itself as between the first and second harvest years (see Table XIX), but in this case the nitrogenous fertilizer was withheld during the mid-season of the second harvest year.

TABLE XXI.—*To show the percentage increase of nitrogen over control for the average yield of the indigenous strains of each species for the four harvest years of the Penglais trial.*

Species.	Percentage increase of nitrogen over control.			
	1927.	1928.	1929.	1930.
Perennial rye-grass	79	72	34	29
Cocksfoot	30	76	46	33
Timothy	53	77	28	48
Meadow foxtail	84	86	53	19
Fine-leaved fescue	30	62	53	52
Average	55	74	43	36

The results from Penglaise would seem to indicate that with a falling off in plant population per area and in the productivity of the pure strain as such per plot, nitrogen becomes less efficacious as a stimulating influence. The implications of

this result will be dealt with in connection with the larger question of diminishing yield. In so far as the species are concerned it is to be noted that meadow foxtail shows the greatest and red fescue the least diminution in response to nitrogen from the second to the fourth harvest year.

The general behaviour of the individual species and strains in relation to nitrogen is best studied by reference to the Penglais results (Table XVIII). Here we see the cumulative effect of three years of treatment and on plots which were exceptionally uniform. Reference to the last column of the table shows that on the whole perennial rye-grass and meadow foxtail responded more freely to nitrogen than did cocksfoot or timothy. In the first harvest year, while still abundant on the plots, golden oat grass (see Tables XVIII and XX) and tall oat grass (see Table XIX) are capable of exaggerated response to nitrogen—their pasturage, however, consists of a succession of stemmy "hay" crops. The evidence from the three fields taken together suggests that the red fescues make very good response to nitrogen in terms of pasturage, and would seem to indicate that Yorkshire fog is perhaps not affected to the same degree as the generality of species.

The effect of nitrogen was noteworthy in two important respects as influencing all strains alike. In the first place, the without-nitrogen plots exhibited winter burn to a marked degree some weeks before the with-nitrogen plots. In the second place the with-nitrogen plots were always more even in their growth than the control plots.

The Yield of the Various Species and Strains Compared.

Just as in the case of hay *cum* aftermath, so with pasture when the present results are considered together with those previously obtained it is obvious that there is no constancy in regard to the strains which yield most highly. The species and strains fall into high and low yielding groups. Now one and now another particular strain in the former class will take the first position in the various trials.

The precise method of management under which a particular experiment is conducted is usually the decisive factor which determines the relative position taken by the several strains. Thus in the present series of experiments the lenient grazing was very favourable to cocksfoot, which outyielded perennial rye-grass. This was particularly marked on Penglais where we have data for three (and in the case of some strains four) harvest years. In the fourth harvest year indigenous cocksfoot (with-nitrogen plots) gave a yield of 49 lb. of air-dry fodder (per 1/100th acre plot) compared to 38 lb. on the equivalent plot given by indigenous perennial rye-grass. On Barn Field (in a previous experiment)* where the plots were subjected to the drastic influence of the mowing machine, perennial rye-grass (on the sum of four harvest years) gave yields of over 40 per cent. in excess of cocksfoot.

Again in the present trials where the grazing was effected by sheep those strains which were peculiarly unpalatable were less drastically treated than those which were of average palatability.† To this fact in considerable measure must be attributed the very heavy yields of the red fescues which on Penglais (sum of four harvest years with- and without-nitrogen plots) took rank as the strains of highest productivity, and this by a very considerable margin. Thus on Penglais the indigenous red fescue on the sum of the four harvest years gave a yield of 40 per cent. in excess of indigenous cocksfoot which took second place. On Barn Field on the other hand, where all species and strains were subjected to the drastic

*See Stapledon and Davies (1930).

†The fact that all plots alike were scythed down after each grazing was not sufficient to counteract the influence of differential palatability.

influence of the mowing machine, the red fescue, although highly productive, was not as high yielding as perennial rye-grass and a number of the larger grasses.

Again of the more persistent strains none was of such high palatability as indigenous timothy, and no plots were so drastically treated by the sheep as these. On Penglais (sum of three and four harvest years) the indigenous cocksfoot strains taken together outyielded the indigenous timothy strains (with- and without-nitrogen plots) by a considerable margin. On Barn Field, where the cocksfoot and timothy were subjected alike to the mowing machine, the indigenous timothy exceeded the indigenous cocksfoot by an even wider margin. That aggregate yield on the sum of a number of harvest years, other things being more or less equal, tends to be in inverse proportion to palatability is further shown by the fact that of the two indigenous strains of perennial rye-grass the higher yield was recorded from the slightly less palatable (No. 1413, see p. 18). The same was true of the two strains of indigenous cocksfoot—the less palatable, and the one of which the smaller amount was eaten (No. 1640 see p. 18) giving considerably the higher yield. In hay *cum* aftermath, where of course palatability was not a disturbing factor as influencing productiveness and having regard to the with- and without-nitrogen plots, the difference in yield between the contrasting strains was hardly significant and if anything was in favour of the " palatable " cocksfoot and of the "unpalatable" rye-grass.

To turn now to a general review of the position taken by the several species and strains, the comparatively high place taken by golden oat grass in the first harvest year, followed by a rapid fall to insignificance in subsequent years, is to be noted. The little evidence available in respect of tall oat grass and *Bromus arvensis* suggests that these species behave in a similar manner, and that all three species are utterly unsuited to conditions that involve compulsory and intermittent hard grazing no matter if the intervals of rest are prolonged. Yorkshire fog evidently has to rank with the high producing pasture grasses, having yielded well in both first and second harvest years ; no evidence is, however, available relative to its behaviour in subsequent years. Indigenous meadow foxtail takes decidedly higher rank as a pasture than as a hay *cum* aftermath strain ; in the latter category it could not be placed with the high yielding strains. On the sum of four harvest years (Penglais), and on the average of with- and without-nitrogen plots, it gave practically the same yield as indigenous cocksfoot and was thus second only to indigenous red fescue. This marks indigenous meadow foxtail as a very important pasture grass and its achievement is the more noteworthy since its coefficient of palatability was greater than that of indigenous cocksfoot. Meadow fescue has given decidedly high yields (first and second year, Pond Field). Tall fescue has not given as high relative yields as on Barn Field, a fact which is probably due to the heavy grazing to which the sheep subjected this plot early in the spring. Of the less highly productive grasses, it is interesting to note that crested dogstail and sweet vernal grass (which yielded remarkably well) gave increased yields in the second harvest year (Pond Field), and this despite the fact that the final (April) cut was not made in the second year and that rough-stalked meadow grass gave higher yields over a period of two harvest years than would perhaps have been generally expected. The evidence for the smaller grasses is not complete, however, since they were not included in the Penglais trial. It shows, however, that the gap between the " smaller " and " larger " grasses is not as great as is usually assumed, and in this connection the high yields of " brown top " (*Agrostis tenuis*) and crested dogstail on Cwm Field in the first harvest year are of decided significance.

Although the system of grazing was lenient the indigenous strains have

definitely outyielded their commercial counterparts by the second harvest year alike on the with- and without-nitrogen plots. By the third and fourth years (Penglais) the ratios (average of with- and without-nitrogen plots) respectively were as under :—

Third harvest year.	Commercial	indigenous	100 :	161
Fourth ,, ,,	,,	,,	100 :	235

The greatest contrast between the indigenous and commercial strains shows itself in the case of timothy and meadow foxtail. Indeed the high pasture value of the indigenous strains of these two grasses is the outstanding fact brought out by these trials. A fact of the greater importance because it but supports the evidence—evidence albeit in itself much less complete—of earlier trials.

For the rest the position taken by the indigenous red fescue needs to be very seriously considered in relation to the drawing up of seeds mixtures for grazing purposes. The sustained and high productivity of the indigenous strains of perennial rye-grass and cocksfoot must not be overlooked, while the fact that New Zealand cocksfoot has substantially outyielded ordinary Danish should serve as a reminder of the value of the former strain.

DIMINISHING YIELDS FROM YEAR TO YEAR.

Reference to Table XVIII (Penglais) shows that the yield of the species and strains tends to fall off from year to year. This is a remarkable phenomenon which has presented itself in connection with all the trials conducted at the Station. The phenomenon has shown itself to be one of general occurrence as affecting prepared swards both with reference to pasture and to hay *cum* aftermath yields. The tendency has been the same no matter whether we are concerned with pure species plots or with seeds mixtures. The diminishing yields may be masked if the weather conditions are much more favourable in a later than in an earlier harvest year. Such appears to be the only exception to the general rule of diminishing yields. This masking influence of favourable weather is demonstrated by the Pond Field results. The first harvest year was " dry " 1929 and the second harvest year " wet " 1930. On the average of all species and strains the yields from the without-nitrogen plots were slightly higher in the second harvest year (1930) than in the first (" dry " 1929) and this despite the fact that the final grazing was omitted in 1930 (see Table XIX). On the with-nitrogen plots the yields were, however, higher in the first harvest year ("dry " 1929). The ratios were as under :—

	1929	1930
With-nitrogen	100	81
Without-nitrogen	100	107

This difference in respect of nitrogen was probably, however, in no small measure due to the fact that the mid-season applications of the nitrogenous fertilizer were withheld in the second (" wet") harvest year. The result none the less serves to indicate that nitrogen greatly assists in maintaining productivity during droughty periods and is by that much confirmatory of the more complete evidence brought forward elsewhere in this *Bulletin**.

The same relationship was shown relative to the hay *cum* aftermath yields on this field where, as previously stated, the drop in yield from the first ("dry " 1929)

*See page 117.

to the second (" wet " 1930) harvest year was more pronounced on the with- than on the without-nitrogen plots. The reason being that relatively a much better response was given to nitrogen in the dry than in the wet year. In "dry " 1929 the increase in hay *cum* aftermath due to nitrogen was 128 per cent. compared to 78 per cent. in " wet " 1930.

However, when a dry year falls at a later period (*i.e.* subsequent to the first harvest year) that is to say, when the plants have fallen in inherent capacity for production, nitrogen does not appear to be competent to stay the fall in yield which occurs normally from one year to the next ; nor does it minimise the extent of the fall due to adverse season as distinct from increasing age. That such is the case is shown by the Penglais trial for which " dry " 1929 was the third harvest year (see Tables XVIII and XXI and previous discussion).

The importance of the present data with respect to diminishing yields is just this fact that nitrogen although added in incremental doses throughout the whole period of an experiment is incapable of staying the diminution of yield from year to year. The yield on the with-nitrogen plots is of course greater than that on the without-nitrogen plots even in the later harvest years, but as previously shown the percentage increase due to nitrogen falls off as the years advance. The crucial point in the present connection being that the yearly relative diminution in yield is just as great on the with- as on the without-nitrogen plots. The extent and trend of this yearly diminution is well shown in Table XXII. This table has been compiled from the Penglais data and is based on the yields given by the particular strains from which pasture samples were obtained right through to the end of the fourth harvest year. An examination of the table confirms what we have just said and shows in a striking manner the extent to which the yield falls off. The indigenous strains have shared in the same general fate as the commercial but they have differed markedly in degree and have maintained relative yields altogether better than their non-indigenous rivals, the figures for the fourth harvest year being strikingly in favour of the indigenous-pedigree strains.

TABLE XXII.—*To show relatively (with the yield in the first harvest year placed at* 100) *the diminishing yields from the first to the fourth harvest year. The figures have been calculated from the yields for the particular strains from which data were obtained right through to the end of the fourth harvest year, viz., respectively from the indigenous and commercial strains of perennial rye-grass, cocksfoot, timothy, meadow foxtail and red fescue. Penglais trial.*

Strain and treatment.		Harvest years.			
		1st.	2nd.	3rd.	4th
Commercial ..	With-nitrogen	100	49	25	15
	Without-nitrogen. ..	100	50	33	19
Indigenous ..	With-nitrogen	100	79	47	35
	Without-nitrogen. ..	100	62	42	30

The evidence of the figures in the table affords an excellent example of a measure of achievement by " strain " in a sphere where nitrogen is incapable of

achievement. A second such example will be demonstrated when discussing seasonal productivity.

Our earlier trials had been conducted without nitrogen being brought into the scheme of manuring and without the plots benefiting by the excrement of animals. We now see that neither one nor the other addition is competent to stay the diminishing yield of a pure species.

Further reference to Table XVIII (Penglais) shows that the phenomenon we are discussing affects all species and strains alike. The only partial exceptions are the indigenous red fescue and one of the strains of indigenous cocksfoot, both of which yielded more heavily in the second than the first harvest year, but by the third harvest year even these strains were less productive than they were in the first year.

On the basis of what has already been said as to ingress of weeds, and as to persistency, it is not to be expected that the yields of the pure strains as such would be maintained from year to year. The fact remains, however, that in respect of a large number of the strains under test yield falls off to an altogether greater extent than would seem to be justified by either diminishing " plant stand " or by increasing weediness. These two causes are quite sufficient to account for the rapid falling away of grasses like golden oat grass and tall oat grass, but are utterly inadequate as an explanation in respect of such markedly persistent strains as indigenous red fescue, indigenous cocksfoot and indigenous perennial rye-grass.

Indigenous cocksfoot, for example, maintained its number of plants per unit of area without diminution into the fourth harvest year, and the number of tillers only showed a decrease of 15 per cent. from the second to the fourth harvest year, yet the yield in the fourth year was only 39 per cent. of that of the first. This is in full accord with results previously obtained by Davies* which showed that even in the case of the more persistent strains the yield per plant and the number of tillers per plant tended to decrease as the years advanced. It is evident, however, that the yield per plant decreases to a much greater extent than does the number of tillers per plant. Yield, however, is also a function of the size of the tiller. Thus in the fourth harvest year the number of tillers per unit of area on the with-nitrogen plot of indigenous cocksfoot was five times as many as on the corresponding plot of the commercial strain, yet the yield of the indigenous strain was only double that of the commercial. The tillers of the commercial strain were, however, decidedly larger than those of the indigenous. In connection with all these experiments it has been noticed that the size of tiller also tends to decrease as the years advance and this decrease in size of tiller is probably more pronounced in the case of the leafy pasture types than in that of the stemmy hay types. Thus the shorter lived hay types are more productive per tiller than are the longer lived pasture types and this is particularly pronounced in the case of cocksfoot. This is well shown by the quotient yield per plot tillers per area. The quotients are given below for the second, third and fourth harvest years in the case of cocksfoot.

	Second Year.	Third Year	Fourth Year.
Indigenous	0.082	0.057	0.058
Commercial	0.107	0.139	0.153

The figures show that the individual tillers of the commercial strain have been more productive than those of the indigenous, and that the " commercial " tillers

*See Davies (1928).

have maintained and even increased their relative productive capacity from year to year. Thus it comes about that great as is the contrast between the yield of the indigenous and commercial strains in the later harvest years, it is not as much in favour of the former as the appearance of the plots would perhaps suggest.

It follows from what has been said that diminishing yield results from two main causes. Either the plant population may be drastically reduced consequent upon radically unfavourable conditions, such as those superimposed by the management to which the plots are exposed. Thus certain species are quite unable to stand up against repeated defoliation and are probably killed off by this means quite independently of the influence of competition with invading volunteer plants. This is the case with golden oat grass, for example. Other species or strains are greatly weakened by the regularized defoliation and consequently suffer to an exaggerated extent in competition with invading plants which are well able to withstand such drastic treatment and die out in consequence of this two-fold action ; such are the commercial strains of timothy, cocksfoot and perennial rye-grass in varying degree. In other and in the most interesting cases the plant population is not diminished, but the vigour of the individual plant wanes and this shows itself in a reduction of tillers per plant and/or of yield per tiller. This is the case which we have exemplified by the behaviour of indigenous cocksfoot. The question arises as to whether plants which behave in this manner are exhibiting the phenomenon of degeneration or senility. The whole trend of the horticultural evidence relative to this condition shows that " degeneration " should not be lightly accepted as an explanation for diminishing returns per plant. Direct proof of degeneration would seem to be lacking in practically all cases that have been subjected to critical study.

The influences of changes, and particularly of progressive changes, in the environment are generally sufficient to account for a retardation in vegetative vigour in plants which are maintained by vegetative reproduction.* A grass plant is of course a clone population and maintains itself by a unique process of vegetative perpetuation and consequently may probably be regarded as peculiarly sensitive to progressive environmental changes. The changes that take place on a prepared sward are both progressive and fundamental. The sward is initiated under completely arable conditions on a soil that is friable and well aerated—root development is unhampered. As soon as the seedlings establish themselves, " mat" formation may be said to have commenced. Turf development proceeds rapidly, helped as it always is by the ingress of volunteer species generally including wild white clover. Consolidation follows and the edaphic environment must change completely, and assuredly changes in a direction less favourable to plant growth just as the plant population becomes intensified and greater calls are being made on the soil. Single spaced plants grown under arable conditions, or grasses grown in drills and on land that is maintained in a clean and friable condition tiller profusely, while the tillers tend to be large in inverse proportion to the amount of crowding that is permitted. Plants grown in this way give extraordinarily heavy yields.

The fact is that plants are small on a fully developed turf just because they have not room to be large ; while the tillers tend to be small because the regularized grazing restricts root development, a restriction that is further accentuated by progressive consolidation and decreasing aeration of the soil below a sod which continues to increase in density. This question of the density of a sward or of

*For a recent review of the subject see Bijhouwer (1931).

"sole" is undoubtedly of fundamental importance. *Agrostis* and wild white clover are "intruding" plants which greatly hasten density with all its disadvantages. Wild white clover, however, carries with it great advantages, since it tends to maintain fertility and is itself highly nutritious and helps to keep out undesirable weeds. It is possible that the fact that wild white clover was more abundant on the without-nitrogen than on the with-nitrogen plots (as has been previously shown) may have had something to do with the phenomenon that the diminishing yield of the pure grass strains on the former plots was no steeper than on the latter. When, however, the extent of the physical alteration in the edaphic environment and in the botanical personnel of a developing sward is fully appreciated it will be realized that any controlling influence exercised by the mere amount of plant foods actually present can only be of secondary importance. Such is the undoubted implication of all the results of the trials under discussion in relation to this phenomenon of diminishing yields.

In the last resort the whole question is largely one of competition. But competitive influences must be considered very largely from the point of view of their effect upon the condition of the soil underlying the turf and on the turf as such and not merely from the point of view of the direct reaction of one species upon another. In practice the problem with which the farmer is faced is how to maintain a sward in a sufficiently open condition and at the same time free from out and out weeds and sufficiently full of white clover. At present we can do no more than draw attention to the problem; to have stated a problem is, however, to have taken the first step towards its solution. The probability is that the mechanical cultivation of pastures will come to be something very different from what is at present envisaged by even the most thorough-going advocates of such treatment. While from the point of view of producing early grass it may be found remunerative to grow super-early strains under conditions of high manuring in cultivated drills.

Leaf Yield.—On the score of nutritive value, leaf production is the essential thing, and consequently the yields given by leaf as such (the blade or lamina, as opposed to stem proper or to sheath) afford an excellent criterion for judging the rival merits of the various species and strains. Unfortunately, it was only possible to make leaf analyses (which are exceedingly laborious) in connection with the Penglais experiment. Such analyses could only be undertaken for all species and strains in the first harvest year and for selected strains in the second harvest year. The essential evidence is set out in Tables XXIII and XXIV. In the latter table the figures appertain to individual lots and are not averages for several strains of some of the species as in the case of Table XXIII.

Reference to Table XXIII shows that nitrogen although of course greatly increasing the leaf yield as such does not increase the percentage of leaf contributing to the whole produce (stem and leaf). This behaviour is essentially the same as was noted in respect of hay *cum* aftermath and is entirely confirmatory of earlier experiments. In the matter of strain it will be noted that in all cases (and on both the with- and without-nitrogen plots) the indigenous strains offer a herbage with a higher percentage of leaf than do the commercial. The poor leaf contribution made by golden oat grass and Italian rye-grass is again brought into prominence. The very high leaf yield (and high percentage leaf contribution) of indigenous meadow foxtail is in accord with earlier results and stands as further evidence of the immense value of this strain as a pasture plant. Commercial cocksfoot, as always in the first harvest year, gives a very high leaf yield.

The figures in Table XXIV, in which a comparison is made between the first and second harvest years, are very informative. In the first place it is to be noted

TABLE XXIII.—*To show the leaf yields, in lb. of air-dry fodder per 1/100th acre plot, and the percentage of leaf in the yields of whole plant for the first harvest year pasture of the Penglais trial. Also the percentage increase of nitrogen leaf yield over that for control.*

Species and strain.	Nitrogen.		Control.		Percent. increase of nitrogen leaf yield over control.
	Leaf yield.	Percent. leaf in yield of whole plant.	Leaf yield.	Percent. leaf in yield of whole plant.	
Perennial rye-grass : indigenous ..	93.0	71	54.7	73	70
„ Jædersk ..	69.2	69	41.4	78	67
„ commercial ..	94.2	67	52.4	67	80
Italian rye-grass : pedigree ..	65.3	59	44.4	61	47
„ commercial ..	56.8	57	41.1	55	38
Cocksfoot : indigenous	88.4	81	73.2	79	21
„ New Zealand	92.2	78	57.9	77	59
„ commercial	93.9	66	84.0	77	12
Timothy : indigenous	74.9	71	49.0	73	53
„ commercial	48.3	65	32.7	64	48
Meadow foxtail : indigenous	114.0	83	67.0	85	70
„ commercial	76.7	74	38.2	73	100
Fine-leaved fescue : indigenous	99.7	81	79.2	81	26
Golden oat grass : commercial	52.0	50	37.4	50	39
Average for indigenous strains	87.1	73	57.7	74	51
Average for commercial strains	74.0	66	49.7	67	49

that even in the first harvest year in leaf yield the advantage is quite appreciably with the indigenous strains, although in total yield the commercial strains (of the species under direct comparison) had held their own, while in the second harvest year the difference is greatly widened and much more in favour of the former strains. Thus in the second harvest year on total yield the ratio commercial to indigenous (average of with- and without-nitrogen plots) is 100 : 164, while on leaf yield the ratio is 100 : 177. Indigenous meadow foxtail and indigenous cocksfoot (which has now changed places with the commercial strain) give outstandingly high leaf yields in the second harvest year; both strains on the basis of the average figures (with- and without-nitrogen plots) give a higher yield of leaf than does indigenous perennial rye-grass. This leaf evidence therefore gives further point to the high productivity of the two former strains, and there can be no doubt that under a system of management that does not constitute too heavy grazing and yet converts the leafage produced, an enormous amount of nutritive fodder can be obtained and utilized from the pedigree strains of the foxtail and cocksfoot.

The results obtained from these two strains in particular indicate that it might be a feasible and remunerative practice to grow such strains rather as kale is grown, and to " hurdle" sheep across the breadth, always taking the leafage in what would generally be regarded as a too advanced condition. As has been pointed out previously, during the growing season proper the leafage of cocksfoot and meadow foxtail maintains active growth for a considerable period ; and even in an advanced stage will be converted if the animals are " held to their ration "—and this holding of animals to their ration is an essential feature of " hurdling" and folding.

TABLE XXIV.—*To compare the degree of leafiness in the pasture yields for three indigenous and three commercial grasses in the Penglais trial for the first and second harvest years. Yields in lb. of air-dry fodder per 1/100th acre plots.*

Species and strain.	Harvest year.	Nitrogen.			Control.		
		Yield of leaf.	Yield of whole plant.	Percent. leaf.	Yield of leaf.	Yield of whole plant.	Percent. leaf.
Perennial rye-grass : indigenous 1412	1	99.9	132.8	75	62.5	79.8	78
	2	55.5	67.9	82	31.9	39.0	82
Perennial rye-grass : commercial	1	94.2	143.5	66	52.4	78.5	67
	2	49.1	68.8	71	23.5	31.8	74
Cocksfoot : indigenous 1163	1	99.3	121.9	82	71.5	90.0	80
	2	65.3	82.2	80	35.6	42.9	83
Cocksfoot : commercial	1	93.9	141.4	66	84.0	109.0	77
	2	35.3	45.6	77	22.8	26.5	86
Meadow foxtail : indigenous	1	114.0	138.7	82	67.0	79.0	85
	2	69.5	79.8	87	30.5	35.2	87
Meadow foxtail : commercial	1	76.7	103.4	74	38.2	52.6	73
	2	19.7	23.7	83	12.5	14.6	86
Average for indigenous strains	1	104.4	131.1	80	67.0	82.9	81
	2	63.4	76.6	83	32.7	39.0	84
Average for commercial strains	1	88.3	129.4	68	58.2	80.0	73
	2	34.7	46.0	75	19.6	24.3	81

The data in Table XXIV are in accord with previous evidence as showing that the percentage leaf contribution is higher in the second than in the first harvest year. This is an occurrence which is difficult to account for, but it appears to be associated with the phenomenon of diminishing yields. With a falling off in " vigour ", no matter what the cause of the falling off, gramineous plants would seem to become increasingly leafy. From the point of view of nutritive value, diminishing yield is therefore to some extent compensated for by increased leafiness—yield of leaf does not diminish as steeply as total yield.

In this connection it is of interest to observe that the commercial strains which fall in yield in a much more pronounced manner than the indigenous show decidedly the greater relative increase in leafiness from the first to the second year.

SEASONAL PRODUCTIVITY.

Seasonal productivity of necessity has been dealt with, although incidentally, when discussing seasonal palatability and amount eaten. Certain points are,

however, of sufficient interest to be considered in greater detail and with explicit reference to yield as such. The late autumn, winter and early spring are the most important periods. By November 8th, 1927, the indigenous strains were by far the more satisfactory. Thus on Penglais (first harvest year) with an average yield for all species and strains of 7 lb. (air-dry fodder per 1/100th acre plot) on the nitrogen plots, and 3.7 lb. on the no-nitrogen, the highest yielding strains were as follows (the first figure is yield on the nitrogen plot and the second on the no-nitrogen plot) : pedigree indigenous perennial rye-grass 12.5 and 5.9 ; pedigree indigenous red fescue 11.7 and 5.4 ; Chewing's fescue 10.5 and 8.7 ; pedigree cocksfoot 10.4 and 3.3 ; and pedigree indigenous meadow foxtail 9.0 and 4.0. The only commercial strain to take a high place was Chewing's fescue and the leafage of this strain, like that of the indigenous cocksfoot, was already beginning to show burn. The outstanding strains were the indigenous perennial rye-grass and the indigenous red fescue.

WINTER PRODUCTIVITY.

Data for December and January productivity (obtained by making special cuts on the plots of such species as were providing a definite measure of keep) are presented in Table XXV. The most interesting point to notice is the uniform relative excellence of indigenous perennial rye-grass. The yield of this strain on January 5th, 1929, is particularly noteworthy. Plate II. fig. 2, shows the with-nitrogen plot of the best indigenous rye-grass (Ba 1412) on that date and reveals a wonderfully uniform and dense herbage. It is important to observe that even in the "dead" season nitrogen exercises a quite appreciable influence on those strains which are capable of making some measure of growth. The contrast between the indigenous and commercial strains of these (the most successful) species is of fundamental significance. On January 5th on the nitrogen plots the indigenous strains were yielding four times as much as their non-indigenous counterparts, the difference being nearly as great on December 9th. The red fescues were only

TABLE XXV.—*To show the winter productivity of indigenous and commercial strains of certain grass species in the Penglais trial. Yields in lb. of air-dry fodder per 1/100th acre plot.*

Date of sampling—	5 Jan., 1928.		5 Jan., 1929.		7 Jan, 1930.		9 Dec., 1930.	
Growth as from—	10 Nov., 1927.		10 Oct., 1928.		23 Oct., 1929.		22 Sept., 1930.	
Species and Strain.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.
Cocksfoot : indigenous 1163	9.4	3.8	4.7	1.7	2.8	1.3	2.2	1.9
„ commercial	5.7	3.0	1.4	1.0	1.0	0.4	0.7	0.4
Perennial rye-grass : ind. 1412	—	—	7.6	5.9	3.1	2.0	4.2	2.5
„ commercial	—	—	2.6	4.1	1.3	1.2	1.1	1.1
Meadow foxtail : indigenous	—	—	6.0	2.2	2.4	1.3	1.4	1.9
„ commercial	—	—	0.6	0.5	0.5	0.7	0.4	0.4
Average for indigenous	9.4	3.8	6.1	3.3	2.8	1.5	2.6	2.1
„ „ commercial	5.7	3.0	1.5	1.9	0.9	0.8	0.7	0.6
Fine-leaved fescue : indigenous	—	—	—	—	—	—	3.8	3.8
„ Chewing's	—	—	—	—	—	—	1.3	1.8

cut on December 9th, at which date the indigenous strain on the average of the with- and without-nitrogen plots outyielded even the indigenous rye-grass. The figures as a whole in the table show that indigenous meadow foxtail and indigenous red fescue (as confirmed by the "amount eaten" data) make a valuable contribution to winter keep.

Spring Productivity.

Interesting data relative to spring productivity are presented in Table XXVI. Data are here available to compare the spring yields "after hay" and "after pasture" and provide evidence which confirms absolutely and completely all previous results from the Station.* The present results are the more noteworthy because (1) the "pasture" is true pasture resulting from normal defoliation by sheep, and (2) the grazing was not drastic and was indeed such that the sum of the pasture yields was actually greater than the sum of the hay and aftermath (see last section). On examining the table we see that on March 26th with only a single and negligible exception (commercial meadow foxtail plus nitrogen) and taking into account both the with- and without-nitrogen plots, the "after hay" yields have substantially outyielded the "after pasture" to the extent of 100 per cent. on the average figures. This effect is continued into April and May for certain strains in particular, but on the average of all species and strains the difference is not then pronounced. The March result has been most pronounced in the case of Italian rye-grass; very pronounced in the case of cocksfoot, particularly the commercial strain, and timothy, particularly the commercial strain. It has been least pronounced in the case of the rye-grasses, meadow foxtail and red fescue. This difference between "after pasture" and "after hay" which we are discussing has continued to show itself in the most pronounced form into April and May in the case of cocksfoot.†

Here then we have a state of affairs in which all our trials are in remarkable agreement, not only in so far as the general phenomenon is concerned, but also in the behaviour of the individual species and strains. The practical significance is of the first importance and once more serves to emphasise that the master factor influencing the productivity of grassland at any particular moment is management; in other words, the scheme upon which fields are rested. The management of the grassland of a farm should aim at catering for every "particular moment" the whole year round. For the rest, our figures show that March grass can be produced in sumptuous quantity: firstly, by proper resting; secondly, by resting the proper strains, and thirdly, by a judicious use of fertilizers (including nitrogen) on these proper strains adequately rested. The March figures in the table will well repay most critical scrutiny—compare strain against strain, "after hay" against "after pasture," with- and without-nitrogen. Italian rye-grass, cocksfoot, meadow foxtail (indigenous) and red fescue will be seen to be the most important March species. If in the case of these grasses we compare the average yield "after pasture" without-nitrogen with "after hay" with-nitrogen we get the very striking ratio 100 : 370.

This is a perfectly legitimate comparison to make, and one which represents very normal differences such as occur in farm practice. Thus we see that a proper choice of strains, supported by appropriate manuring and management, makes just the difference between substantial and negligible March productivity. The outstanding position taken by indigenous meadow foxtail and indigenous red fescue is the most striking feature of the April (a month when "keep" is still very

*See Stapledon (1924).
†Cf. Jones and Jones (1930).

TABLE XXVI.—*To illustrate the superior pasture yield obtained in the spring from pasture after hay as compared with pasture after pasture. Yields in lb. of air-dry fodder per 1/100th acre plot for the first three grazings of 1928 in the Penglais trial.*

Species and strain.	Treatment.	26th March.		24th April.		15th May.	
		Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control.
Perennial ryegrass : indigenous	Pasture after hay ..	6.1	7.8	9.4	6.1	11.6	7.2
	Pasture after pasture ..	5.9	3.8	8.9	6.2	12.8	7.0
„ commercial	Pasture after hay. ..	7.7	5.4	12.4	11.6	11.3	5.7
	Pasture after pasture ..	6.2	3.8	17.1	9.5	12.8	4.7
Italian rye-grass : pedigree	Pasture after hay. ..	12.0	3.8	9.6	3.6	8.1	7.2
	Pasture after pasture ..	3.0	0.5	8.5	2.0	6.8	3.2
„ commercial	Pasture after hay ..	11.1	4.2	11.2	4.7	10.0	6.2
	Pasture after pasture ..	0.6	1.0	3.7	2.3	5.5	7.4
Cocksfoot : indigenous	Pasture after hay ..	13.4	9.7	17.5	10.7	19.3	12.1
	Pasture after pasture ..	5.0	3.2	8.8	5.7	11.6	5.8
„ commercial	Pasture after hay ..	9.7	5.8	13.6	6.0	9.3	7.6
	Pasture after pasture ..	3.3	2.1	4.9	5.1	8.2	3.0
Timothy : indigenous	Pasture after hay ..	6.1	2.7	6.9	2.9	7.2	7.4
	Pasture after pasture ..	5.2	2.0	4.5	2.7	7.7	6.4
„ commercial	Pasture after hay ..	6.2	5.2	6.8	3.1	12.7	8.0
	Pasture after pasture	1.7	1.1	2.8	2.0	6.7	5.0
Meadow foxtail : indigenous	Pasture after hay ..	11.6	7.9	22.1	9.7	18.7	8.6
	Pasture after pasture ..	8.6	5.9	20.1	8.4	10.3	5.3
„ commercial	Pasture after hay ..	2.8	4.1	5.3	3.3	8.3	4.3
	Pasture after pasture ..	3.2	1.1	3.8	2.3	2.7	2.6
Average for all grasses*	Pasture after hay ..	8.7	5.7	11.5	6.2	11.7	7.4
	Pasture after pasture ..	4.3	2.5	8.3	4.6	8.5	4.7
Fine-leaved fescue Chewing's †	Pasture after hay ..	12.5	13.0	15.3	12.3	22.8	18.7
	Pasture after pasture ..	7.5	6.3	18.5	11.3	20.7	14.8
Red fescue : indigenous ‡	Pasture after pasture ..	10.3	7.7	20.7	12.3	—	—

* Fine-leaved fescue not included in the averages.
† Indigenous fine-leaved fescue was absent from the hay series of plots.
‡ Figures for March and April 1928 for comparison.

short) yields ; commercial perennial rye-grass and commercial cocksfoot are also high yielding at this date. The importance of indigenous red fescue and indigenous meadow foxtail is thus once again brought into prominence—they have the great advantage over Italian rye-grass in particular, but also over the commercial strains of cocksfoot and perennial rye-grass, that they are persistent and under proper management are competent to make an important contribution to early spring keep for a number of years.

The exceptionally high spring yield of the indigenous red fescue " after pasture" in comparison with altogether more palatable species, such as perennial rye-grass and meadow foxtail, to a very considerable extent would have been due to the fact that it was not as heavily grazed throughout the previous year as the more palatable strains. The inherently high spring productivity of red fescue considered as a species is, however, abundantly shown by the position taken by Chewing's fescue after hay *cum* aftermath* (when all species and strains were subjected to identical treatment) in comparison with other high yielding spring species. This consideration merely adds emphasis to the extreme importance of management relative to providing pasturage for critical periods of the year.

Seasonal Productivity Throughout the Growing Season.

The data are too extensive to attempt to discuss in detail the seasonal behaviour of all the species and strains under test. The most important points, however, can be illustrated by typical examples. The first series of graphs (see Text-fig. 1) afford a comparison between the indigenous strains and the commercial strains (of the same species) under test. The results from Penglais have been employed and are given separately for the four harvest years and for the with- and without-nitrogen plots. In comparing the four harvests years it must be remembered that the plots were grazed (and sampled) more frequently in the first than in the subsequent years.† The curves are of the type given by earlier experiments.‡ They show the usual tendency to develop primary (May—June) and secondary (August —September) peaks. That is to say, the growth curve to a large extent is conditioned by the plants' functional periodicity ; the primary peak being developed when the plants tend to run to flower (at hay time) and the secondary peak when secondary inflorescences appear (aftermath time).

Reference to the graphs shows that the commercial strains usually attain to their primary peak in May, while the indigenous (which on the average are later to flower) do not as a rule do so until June. The actual shape of the curve is to a marked degree influenced by weather—pasture growth, as has been shown in previous trials, is particularly responsive to rainfall. This is well illustrated by the curve for 1929. The rainfall was far below normal for January, February, March and April, and it only averaged 3.4 inches per month during May, June, July, August and September. The primary peak was attained to in May for both indigenous and commercial strains, and the secondary peak did not show itself until October with 7.7 inches of rain. There was consequently a steady fall in yield throughout the summer.

In 1928 with a dry May and a wet June the indigenous strains attained to a very pronounced June peak while the commercial strains showed only a very slight peak in May. In 1930 with May and June comparatively dry and July wet the

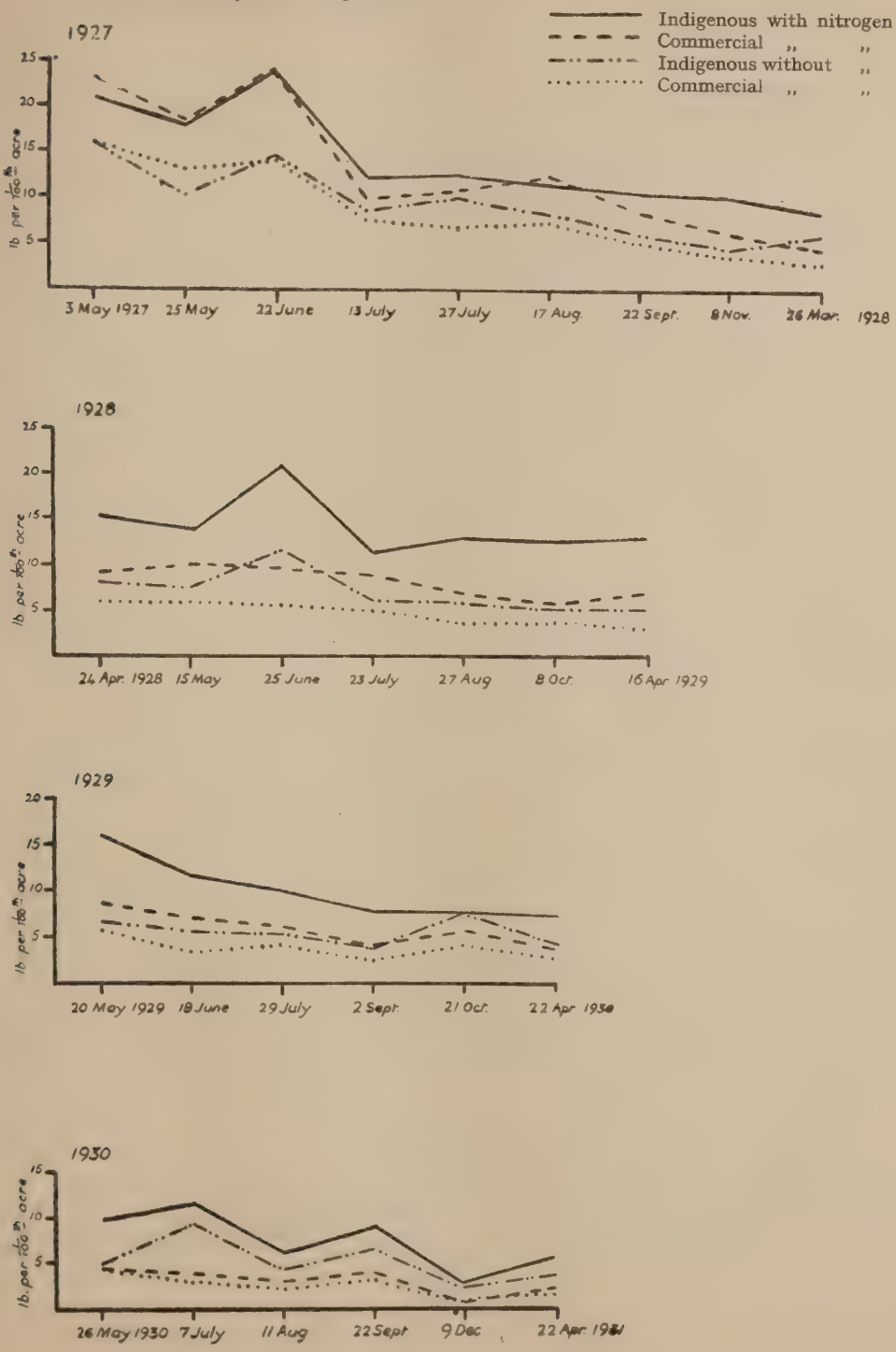
*There was no plot of the indigenous red fescue in the hay *cum* aftermath series.

†Frequent cutting tends to level out the curve ; but on the other hand first harvest year yields are heavier than those for subsequent years, so that on the balance the curves for the four years are reasonably comparable.

‡See Stapledon (1924).

TEXT-FIG. I.

To compare the seasonal productivity (in lb. of air-dry fodder per 1/100 acre plot) for plots treated with and without nitrogen. The results are shown separately for the average of the indigenous strains and for the commercial strains of the same species, and for each of the four harvest years. *Penglais trial.*



indigenous strains did not attain to their primary peak until July. The behaviour of the commercial strains was interesting in 1927. April and May had an average rainfall of only 2 inches and June was wet with 6 inches rainfall. The commercial strains gave a primary peak early in May (functional periodicity), but under the influence of the June rainfall they again rose considerably in yield to give a further peak coincident with the primary peak of the indigenous strains.

Further reference to the graphs shows that in the second, third and fourth harvest years the indigenous strains with nitrogen have substantially outyielded the commercial strains similarly treated at every date in each year, while in the fourth harvest year the indigenous strains without nitrogen have actually outyielded the commercial strains with nitrogen at every date. It will be noted that even in the first harvest year the indigenous strains have given a better seasonal distribution of herbage than have the commercial.

The graphs bring out the further important point that nitrogen is not capable of altering the shape of the seasonal curve to any material extent. The with- and without-nitrogen curves do not of course run absolutely parallel, but in the main they follow very much the same course. Witness, for example, the striking similarity between the two curves for the indigenous strains in all four years—the only marked departure occurring during the autumn of 1929. Be it equally noted, however, that the with-nitrogen curve never crosses the without-nitrogen—at all times the nitrogenized herbage is the heavier yielding.

From the point of view of levelling up seasonal productivity, strain rather than nitrogen is the decisive factor. This is well exemplified by the second series of graphs (see Text-fig. 2).

In these graphs we have plotted the average yields of indigenous rye-grass *cum* indigenous cocksfoot in comparison with the average yields of indigenous meadow foxtail *cum* indigenous red fescue. The yields from the nitrogen plots have been taken and a separate graph is given for each of the four harvest years.

The first harvest year (1927) shows the two curves intersecting at four dates, with the foxtail—fescue superior to the rye-grass—cocksfoot at very important periods, early in the spring and in the middle of the summer. The rye-grass—cocksfoot takes a prominent position at the least important period of the year May, June and early July. In the second harvest year (1928) the foxtail—red fescue is seen substantially to outyield the rye-grass—cocksfoot at all dates. The curves are practically parallel during May, June and July, but are markedly divergent early in the spring. In the third harvest year (1929) the foxtail—red fescue shows to great relative advantage early in the spring and right through the summer ; during the autumn and winter the curves for both sets of strains are substantially similar. In the fourth harvest year (1930) the advantage is still with the foxtail—red fescue, and particularly in the early spring. From July to December the curves for the two sets of strains run more or less parallel.

The practical significance of these results and their relation to the whole question of maintaining seasonal productivity at the highest possible level under farm conditions will be discussed in detail in the general summary and recommendations at the end of this paper.

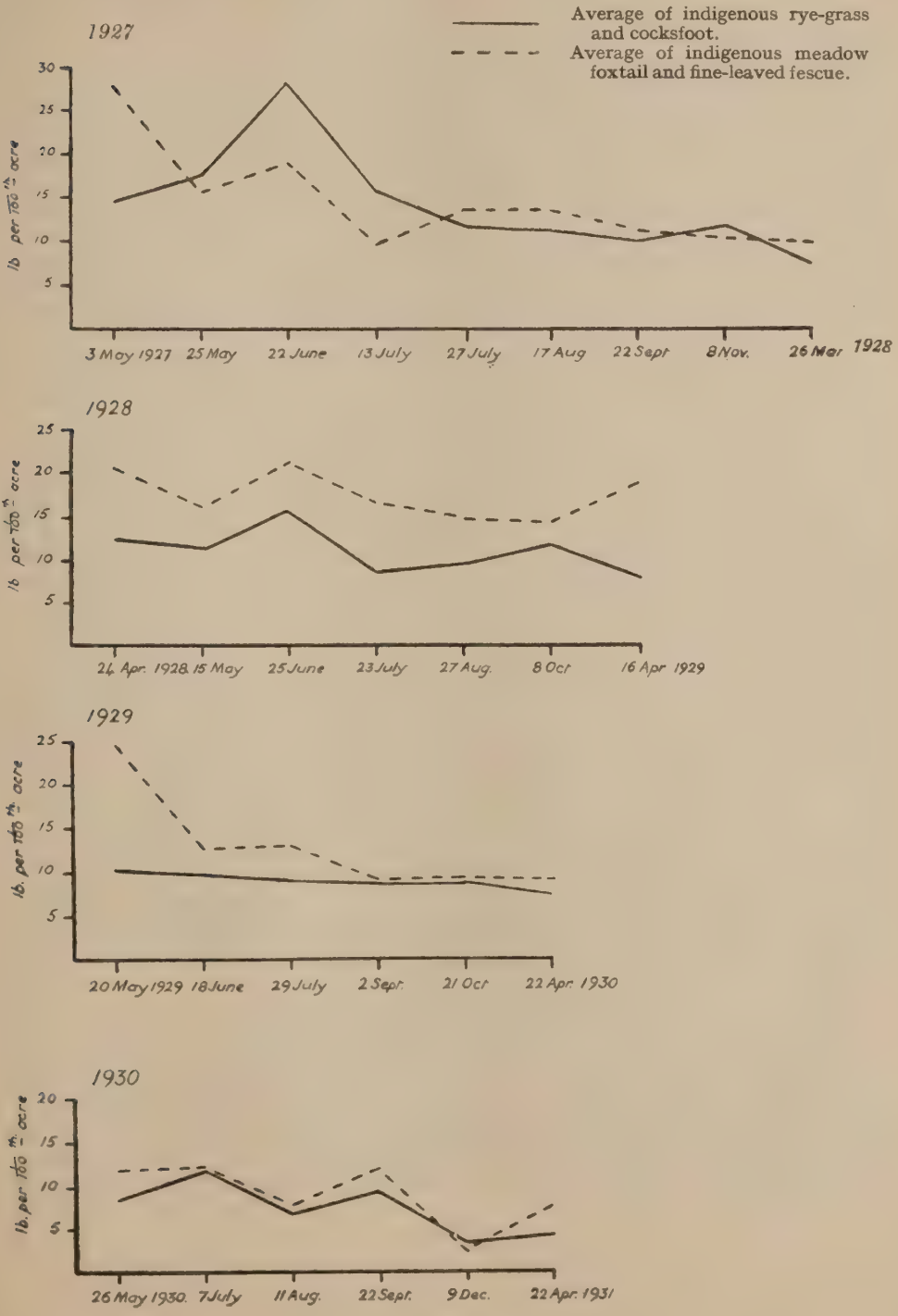
BEHAVIOUR OF THE SHEEP.

This paper is concerned with the herbage and not with the sheep as such. A few points relative to the sheep have, however, been referred to incidentally and in this section a little more may be usefully said on this subject.

When the sheep were first turned in to the folded plots they immediately

TEXT-FIG. 2.

To compare the seasonal productivity (in lb. of air-dry fodder per 1/100 acre plot) of (a) the average of indigenous perennial rye-grass and indigenous cocksfoot with (b) the average of indigenous meadow foxtail and indigenous red fescue. The results are given for the with-nitrogen plots and are shown separately for each of the four harvest years. *Penglais trial.*



devoted attention to the narrow timothy path around the edge and under the hurdles. Even on the timothy plots themselves the edge was always eaten harder than the body of the plot. This despite the fact that on the whole the sheep did not appear to resent the confinement to small plots. Small as were the folded enclosures, the sheep always tended to camp on the upper end of the plots.

The sheep were very much influenced by the state of the weather at the time of grazing. Thus, for example, on July 12th, 1927 (Penglais) the plots were in a particularly attractive condition, the growth was not excessive, and was young and leafy. The amounts eaten were, however, much below the average. Over the period of grazing (24 hours) the average temperature was 60°F., it was windless, very sultry and humid. On the other hand, in the November grazing of the same year, when the herbage was already to some extent showing burn and was not in nearly as " inviting " a condition as on July 12th, the amounts eaten were exceptionally high for the time of the year. Cold and bright weather characterised this particular 24-hour grazing period. These two cases are typical of the sort of differences noted throughout the conduct of all the trials.

It follows that very little reliance should be placed on isolated observations relative to the behaviour of sheep in relation to their pasturage. Experiments must be long continued and at all times supported by critical notes.

Observations at the commencement of the experiment seemed to suggest that the nature of the droppings of the sheep varied somewhat as between the different strains of grasses. In consequence, it was decided to make careful notes on the condition of the droppings on all the plots after each grazing. The method adopted was to classify the droppings as from normal (10 marks) to excessive scour (0 marks).

When all the extensive data had been assembled it was found that the differences were not as great as had been anticipated and consequently need not be considered in detail. Certain points, however, emerged quite definitely and to these brief reference will be made.

There was surprisingly little out and out scouring—only 4 per cent. of the total observations (=all the grazings on all the plots). There was no more scouring on the nitrogen- than on the without-nitrogen plots, but taking all the plots and grazings together the droppings left on the nitrogen plots were a little more laxative than those on the without-nitrogen plots.

The first grazing of the season (early in the spring) always resulted in droppings of a very decidedly more laxative nature than those at other times of the year. At this first grazing the sheep of necessity were always taken off relatively bare pastures. In so far as strain is concerned, it may be definitely stated that at the first spring grazing indigenous meadow foxtail with-nitrogen and perennial rye-grass both with- and without-nitrogen are decidedly more laxative than other strains. At this time of the year actual scouring is not infrequent on these plots. At other times of the year these strains give droppings of similar consistency to those found on the plots of the majority of the other grasses.

SUMMARY AND DISCUSSION.

From the practical point of view the evidence from the present and former trials which we have discussed is perhaps of the greatest significance as showing the individual and specific quality not only of every species but equally of characteristic strains within the species.

It is the essentially quantitative aspect of this individuality that demands our serious attention. We have seen, for example, that each strain has its own and individual coefficient of response in respect of all the factors that influence its value

as a pasture plant. Even closely allied indigenous strains of one and the same species (*e.g.* of cocksfoot, timothy and perennial rye-grass) have been shown to differ in palatability and as to amount of leaf eaten. The species and strains vary markedly in their yielding ability in relation to intensity of grazing. Thus all strains of cocksfoot yield heavily under a lenient system of grazing, while the heavier the grazing the greater the contrasting advantage in favour of the indigenous strain. The indigenous strains of perennial rye-grass maintain high yielding ability under more intensified grazing better than do any strains of the other larger grasses. Species like golden oat grass and tall oat grass are unable to persist even under a lenient system of regularized grazing. The order of merit of the various strains and species is very largely a function of the intensity of grazing actually adopted in a particular trial.

We have shown that palatability is influenced by a variety of factors and is also affected by a number of inherent properties of the plants. And in nothing to a greater extent than in palatability do species and strains exhibit their quantitative individuality. Thus even red fescue and bent are palatable when only permitted a very short growing period. All the evidence suggests that differentiation in relative palatability between species and strains becomes more and more pronounced in proportion as the rest period is lengthened. The leafage of certain species is, however, of unusually high palatability ; such species are Italian rye-grass and timothy. It has been shown that perennial rye-grass and white clover remain palatable in proportion as the leafage ages to a greater degree than do other species. This is undoubtedly one reason that renders them such valuable pasture plants. Palatability has a direct influence on persistency and the power to sustain productivity. Strains which are not grazed hard are liable to persist and to remain productive for a number of years. The high and sustained productivity of indigenous red fescue has probably in a large measure been due to the fact that it was not grazed as hard as other strains. Productivity in the early spring would seem to be influenced more by previous management relative to grazing than by any other single factor. The fact that all species and strains have given considerably more spring keep after hay *cum* aftermath than after pasture constitutes a most important yet elementary lesson in pasture management. The high March-April yields from indigenous red fescue and indigenous meadow foxtail and the high winter yields from indigenous perennial rye-grass are amongst the most illuminating pieces of evidence relative to seasonal productivity.

There is a very pronounced differentiation in respect of the all-important stem : leaf ratio. Indigenous meadow foxtail and indigenous cocksfoot give a very leafy herbage in pasture and aftermath, while the meadow foxtail gives an exceptionally leafy hay. At the other extreme we have stemmy plants like Italian rye-grass, golden oat grass and Yorkshire fog. Golden oat grass is the only species of which the sheep eat practically as much stem as leaf, while the stem of Italian rye-grass is more palatable than the stem of other grasses. Marked individuality is shown by the strains in their power of resistance to intruding volunteer species. Indigenous cocksfoot and indigenous red fescue (under the system of grazing actually adopted be it noted) have maintained themselves in the greatest purity.

The same individuality is to be noted in the response of the strains to nitrogen. In certain very important respects nitrogen must, however, be regarded as a levelling agent in its influence on the various strains. Thus nitrogen by favouring the yield of indigenous strains more than that of the commercial in the hay crop tends to bring the yield of the former, even in the first harvest year, close to the yield of

the latter. In aftermath the normally lower yielding commercial strains are brought more to the level of the indigenous. In the hay crop, moreover, stem-shoot production is favoured to a greater relative extent in the leafy indigenous strains than in the stemmy commercial so that the strains are brought into closer accord in this respect. Nitrogen also tends to increase the palatability of some, but not all, of the relatively unpalatable species.

In other, and equally important respects, nitrogen is without effect or only exaggerates differences. Thus nitrogen does not in the main alter the ratio stem to leaf, nor is it competent to stay the diminishing yield from year to year. Nitrogen is not competent to alter the character of the seasonal growth curve of any strain, but only accentuates seasonal behaviour in a positive and favourable direction. Seasonal productivity can be controlled in what may be described as a qualitative manner by adjusting the scheme of seasonal rest periods in relation to strain *qua* strain and then quantitatively by the judicious use of nitrogen.

The depressing influence of nitrogen on wild white clover as exhibited under the conditions of the trials under review has been noted and tentatively discussed in some little detail. The whole question of white clover in relation to modern views on pasturage and pasture management will, however, be dealt with in a separate publication in the light of further evidence that has been accumulating at the Station.

Speaking quite broadly our evidence permits of our making a sweeping generalisation and a generalisation that goes to the very heart of the theory and practice of pasture management. We can assert that no two species or strains of grass will react in precisely the same way to any single factor that influences seasonal productivity, persistency, palatability or any other property of a sward that affects its economic value. We may then ask how it can ever be possible to manage grassland scientifically. The answer would seem to lie in a simplification of the botanical personnel of swards. To know what we want and when we want it. If variety is needed, to arrange for that variety by moving the animals around fields as such or folds as such, the fields or folds providing what they are intended to provide and when they are intended to provide it.

The question of *ad hoc* temporary leys cannot, however, be exhaustively enlarged upon at the present juncture, because the whole matter is so intimately connected with the "clover problem"; which problem, in our view, is certainly at least equal in importance to the grass problem as such.

Much is written to-day about the "scientific" management of grassland, but we think the evidence discussed in this paper, as indeed that discussed in this *Bulletin* as a whole, should serve to show how very far we are from being in a position to lay down truly scientific rules for the maximum exploitation of grasses and clovers. An enormous amount of critical field experimentation, botanical, nutritional and economic, needs to be conducted on contrasting swards made up of carefully chosen species and strains before we can even claim to have collected the evidence upon which to formulate our scientific rules.

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FIG. 1.

FIG. 2.

FIG. 1.

FIG. 2.

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EXPLANATION OF PLATES I. AND II.

PLATE I.

Fig. 1. Showing the general arrangement of the pasture folds on Penglais Field.
Fig. 2. Commercial plot of cocksfoot on the with-nitrogen fold in January, 1928 (second harvest year). Note the thinness of the sward and large amount of bare ground. Penglais Field.

PLATE II.

Fig. 1. Indigenous plot of cocksfoot (Bc. 1163) on the with-nitrogen fold in January, 1928 (second harvest year). Note the even and dense sward. Penglais Field.
Fig. 2. Showing the relatively abundant and dense herbage produced by indigenous perennial rye-grass (Ba. 1412) on the with-nitrogen plot on January 5th, 1929 (third harvest year). Penglais Field.

THE INFLUENCE OF NITROGENOUS MANURES ON THE CHEMICAL COMPOSITION OF THE PRODUCE OF INDIVIDUAL GRASSES AS PASTURE, HAY AND AFTERMATH.

BY

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The object of the investigation, method of management of the plots and yield of produce has been fully discussed in the preceding paper in this *Bulletin*. The present article is mainly confined to a consideration of the chemical composition of the produce of the grasses and the effect of the application of certain manures on their chemical composition.

In the first place it should be stated that the produce of each grass as pasture, hay and aftermath was separated into stem and leaf, and each separation subjected to chemical analysis. Before proceeding to discuss the effect of the manures on the chemical composition of the grasses, it will assist in the interpretation of the results, if attention is first drawn to certain chemical characteristics of the individual grasses. For this purpose the results from the control plots alone have been considered.

In previous work with individual grasses carried out in seasons 1922 and 1923 (Fagan and Jones, 1924), it was found (though not without exception) that the yield of the grasses as hay was much heavier than their yield as pasture. But in season 1927 it was found that the yield of the same grass as pasture compared with its yield as hay was not only heavier, but considerably heavier, than its combined yield of hay and aftermath.

This is well illustrated in Table I where the yield of dry matter and nutrients of the three grasses giving the highest and lowest yield of pasture, hay and aftermath is shown. It should be pointed out that apart from differences in the climatic conditions prevailing in seasons 1922 and 1923 compared with those of 1927, there was an important difference in the method of management of the plots in the two investigations. In 1922 and 1923 the produce of the plots was cut with shears, whereas in 1927 it was grazed with sheep.

The results in Table I indicate that the greatest amount of nutrients whether as pasture, hay or aftermath, is not of necessity given by the grass showing the heaviest yield. If, for example, the yield and composition of meadow foxtail are taken into consideration, it will be found on comparison to be weight for weight superior to any of the other grasses. In all our investigations with individual grasses, meadow foxtail has always been found to be among the richest in protein and lowest in fibre though not as palatable to sheep as some of the other grasses, *e.g.*, Italian rye-grass and timothy.

The two grasses New Zealand cocksfoot and commercial Italian rye-grass again are practically identical in yield of pasture and approximate closely to each other in yield of hay and aftermath, but the yield of nutrients supplied by cocksfoot is far in excess of that of commercial Italian rye-grass. New Zealand cocksfoot has

TABLE I.—*Total produce (in lb.) of the dry matter of the three grasses giving the highest and lowest yield of pasture, hay and aftermath from an area of 1/100th acre in season 1927.*

	Yield of dry matter.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
PASTURE.						
Cocksfoot, commercial	92.6	14.8	24.7	8.1	0.73	0.55
Fine-leaved fescue	82.6	11.3	23.6	5.0	0.57	0.57
Cocksfoot, indigenous (1640) ..	80.6	12.7	23.3	6.7	0.61	0.62
Timothy, commercial	39.7	6.2	10.1	2.7	0.32	0.25
Meadow foxtail, commercial ..	44.7	8.1	11.1	2.9	0.32	0.25
Perennial rye-grass, indigenous ..	44.8	8.1	11.7	3.6	0.38	0.35
HAY.						
Perennial rye-grass, commercial ..	33.3	1.36	11.87	1.21	0.131	0.158
Cocksfoot, commercial	32.3	1.66	12.39	1.14	0.338	0.124
Italian rye-grass, commercial ..	21.8	1.25	6.45	0.70	0.093	0.10
Timothy, commercial	14.4	1.14	4.12	0.79	0 08	0.08
Cocksfoot, indigenous (1640) ..	12.7	0.95	4.17	0.62	0.07	0.08
Meadow foxtail, indigenous ..	12.3	1.30	3.83	0.70	0.06	0.082
AFTERMATH.						
Cocksfoot, indigenous (1163) ..	10.3	0.93	3.24	0.737	0.042	0.091
Perennial rye-grass, indigenous (1412)	10.2	1.06	2.83	0.54	0.056	0.069
Cocksfoot, indigenous (1640) ..	8.2	0.86	2.78	0.54	0.06	0.07
Perennial rye-grass, commercial ..	3.7	0.34	1.15	0.23	0.03	0.036
Timothy (Grinstad) ..	3.7	0.39	0.98	0.24	0.026	0.023
Meadow foxtail, commercial ..	3.6	0.45	1.15	0.17	0.019	0.022

always given good results in the trials of the Welsh Plant Breeding Station, being superior in yield and leafiness to Danish commercial, and has been found to be the equal of most strains of cocksfoot in chemical composition.

A factor which has a very considerable influence on the chemical composition and nutritive value of the pasture, hay or aftermath of a grass is the proportion of stem to leaf in the produce. The superiority of the leaf over the stem has been emphasised repeatedly, and Table II, which gives the results obtained with commercial timothy (a grass in which this proportion is high), serves to emphasise this fact still further.

If the pasture results be first considered, the contribution of the leaf to the total dry matter is seen to be 65 per cent., whereas its contribution to the total protein, lime and phosphoric acid is 72, 75 and 68 per cent. respectively. Again, though the leaf makes up 65 per cent. of the total dry matter, its contribution to the total fibre is but 61 per cent. These results fully confirm the results of all our previous work with grasses, namely, that the leaf is considerably richer in protein and lime than the stem, while the percentage of fibre is lower.

To the total produce of hay the leaf contributes only 27 per cent., yet the influence of this, small as it is, on the chemical composition of the produce is still evident ; for of the total protein and lime it is from the leaf that 32 and 35 per cent. respectively are obtained.

Of the aftermath 52 per cent. is made up of leaf, but the contribution of the leaf to the total protein and lime of the aftermath is 60 and 73 per cent. respectively.

TABLE II.—*Contribution (in lb.) made by the stem and leaf to the total nutrients of commercial timothy as pasture, hay and aftermath, from an area of 1/100th acre in season 1927.*

	Yield of dry matter.	Ether extract.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
PASTURE.							
Stem	13.6	0.28	1.72	3.88	0.85	0.103	0.057
Leaf	26.1	0.92	4.51	6.20	1.83	0.220	0.200
Total	39.7	1.20	6.23	10.08	2.68	0.323	0.257
HAY.							
Stem	10.40	0.17	0.77	3.15	0.60	0.062	0.036
Leaf	3.98	0.13	0.37	0.97	0.19	0.018	0.045
Total	14.38	0.30	1.14	4.12	0.79	0.080	0.081
AFTERMATH.							
Stem	2.77	0.061	0.25	0.96	0.16	0.022	0.009
Leaf	3.03	0.110	0.39	0.95	0.22	0.024	0.025
Total	5.80	0.171	0.64	1.91	0.38	0.046	0.034

The plot from which hay and aftermath were taken in 1927 was grazed as pasture in 1928, whereas the plot that was grazed in 1927 was again grazed in 1928. For that reason it is of interest to compare the yield and chemical composition of the produce of a grass as pasture following pasture, with the pasture of the same grass following a hay crop. In Table III this is shown in the case of indigenous meadow foxtail 284.

TABLE III.—*Total yield (in lb.) of nutrients of indigenous meadow foxtail 284 from an area of 1/100th acre of pasture following pasture, and pasture following hay in season 1927.*

Yield of dry matter.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
PASTURE AFTER PASTURE.					
Leaf 18.02	3.28	4.45	1.41	0.13	0.13
Stem 3.82	0.54	1.05	0.24	0.03	0.02
Total 21.84	3.82	5.50	1.65	0.16	0.15
PASTURE AFTER HAY.					
Leaf 37.4	7.68	8.44	2.39	0.28	0.26
Stem 6.4	0.84	1.80	0.44	0.05	0.03
Total 43.8	8.52	10.24	2.83	0.33	0.29

The results shown in Table III may be taken as representative of the results obtained with each of the grasses, for in every case the yield of pasture after hay was heavier than the yield of pasture after pasture. Reference to the figures given in the table shows that a more leafy produce was obtained from this particular grass (meadow foxtail) when pasture follows hay than when pasture follows pasture.

In the large majority of the grasses, however, the contrary is the case, that is, the produce is more leafy when pasture follows pasture. A comparison of the total yield of nutrients from the two pastures shows that weight for weight there is not a great deal of difference between them. The protein content of the pasture following hay, as would be expected from the fact that it is more leafy, is higher, but this is accompanied by a higher fibre content. Again weight for weight the two pastures yield practically identical amounts of phosphoric acid and lime, but while the difference in chemical composition between the two pastures is only slight the yield of dry matter from the pasture following hay is considerably heavier.

In assessing the value of individual grasses as food for stock, one of the most important factors is the palatability of the grass. This is extremely difficult to determine in a mixed herbage, though it is well known that stock show a distinct preference for certain grasses over others, and in addition show a greater partiality for a particular grass at certain seasons of the year. In this investigation the management of the plots afforded opportunities for observing any preference shown by sheep for the grasses dealt with. In this connection it is of interest to note that of the grasses under investigation sheep showed a distinct partiality for the pedigree and commercial strains of Italian rye-grass, as well as for timothy, whereas fine-leaved fescue was not grazed with anything like the same avidity. In Table IV the total yield of dry matter and nutrients of two strains of Italian rye-grass, four strains of timothy and one strain of fine-leaved fescue as pasture from similar areas in season 1927 is shown.

TABLE IV.—*Total yield (in lb.) of nutrients from an area of* 1/100*th acre as pasture of six strains of the most palatable grasses, as well as of another grass not so palatable.*

	Yield of dry matter.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Italian rye-grass, pedigree ..	61.53	8.00	14.80	5.04	0.46	0.54
Italian rye-grass, commercial ..	63.61	8.60	16.67	4.76	0.502	0.49
Timothy, indigenous 309	55.44	8.43	14.27	3.63	0.403	0.34
Timothy, indigenous 310	58.96	9.45	14.97	3.95	0.451	0.37
Timothy, Grinstad	46.59	8.00	11.92	3.46	0.38	0.32
Timothy, commercial	39.7	6.23	10.08	2.68	0.32	0.25
Fine-leaved fescue	82.6	11.27	23.56	5.03	0.57	0.57

On comparison, the results (see Table IV) show that of the three pedigree grasses, Italian rye-grass, indigenous timothy and fine-leaved fescue, the least palatable, namely, fine-leaved fescue, gives the highest yield of dry matter as pasture. Further, reference to Table I shows that fine-leaved fescue is one of the three grasses giving the highest yield of dry matter as pasture. If, however, equal weights of the dry matter of the three grasses are compared, timothy is seen to be richer than fine-leaved fescue in protein and phosphoric acid, and to be lower in fibre and slightly lower in lime content. A comparison on a similar basis of pedigree Italian rye-grass with fine-leaved fescue shows the former to be considerably higher in phosphoric acid and lime and lower in fibre, while the protein content of these grasses is very similar. The crude fibre content of a grass may be only one of the factors that influence its palatability, but it is significant to find that the

least palatable of these grasses is much higher in fibre content than the remainder. It should, however, be emphasised that although the grasses under investigation were all grazed at stated intervals, some produced a much more bulky growth than others in the interval between grazings. For instance, cocksfoot in June and July made much more growth than at any other corresponding period, but its palatability, judged by the way it was grazed, was at its lowest at this period.

TABLE V.—*Percentage of crude protein, fibre, silica-free ash, phosphoric acid and lime in the spring, summer and autumn growth of cocksfoot.*

	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Autumn cut, 1927	20.01	22.32	5.86	0.94	0.64
Spring cut, 1928	22.79	18.70	7.16	0.73	0.93
Summer cut, 1928	13.61	30.10	6.73	0.52	0.97
Autumn cut, 1928	20.22	21.20	8.72	1.08	0.70

A comparison of the composition of the spring, summer and autumn growth of cocksfoot shows that of the constituents determined the outstanding difference is to be found in the crude protein and fibre content of the summer growth compared with that of the spring and autumn growth.

This difference is to be seen in the composition of all grasses at this season of the year, but is more pronounced in cocksfoot, compared with the majority of the others, owing to its being a quick growing grass. It may be that the interval between grazing is too long for the best management of the grass, and again it has to be borne in mind that the grazing was by sheep, whereas in actual farm practice it would be by mixed stock. However, the rise in fibre and the fall in protein at this season of the year serve to emphasise the care that should be exercised in the management of the grazing of pastures, and to show how easily as a result of neglect an excellent and valuable grass becomes unpalatable.

Certain grasses appear to be better suited for the purpose of early spring and late autumn grazing than others. Thus if the yields of indigenous meadow foxtail and fine-leaved fescue are compared with those of indigenous perennial rye-grass and cocksfoot, the former are found to give at these seasons a considerably heavier yield of dry matter.

In Table VI the late autumn growth represents that made in October, while the early spring growth is that produced up to the end of March. The latter sample contained a quantity of winter growth which was somewhat burnt, and as a result of this the protein content is low. It was also observed that meadow foxtail and fine-leaved fescue at these seasons were much greener than perennial rye-grass and cocksfoot.

It became evident during the course of the investigation that the stem of certain grasses as pasture was much better grazed than others, and that the stem of Italian rye-grass was one of the best grazed. The contribution made by the stem of Italian rye-grass to the total produce of its dry matter as pasture was 38 per cent., so that the palatability of the stem becomes a matter of some importance in assessing the value of a grass as a constituent of the herbage of pasture.

Other grasses were met with in the investigation, *e.g.*, perennial rye-grass

TABLE VI.—*Yield (in lb.) of dry matter in the late autumn and early spring of four grasses from an area of* 1/100*th acre, together with the percentage composition of the dry matter.*

	Yield of dry matter.	Crude protein	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Indigenous meadow foxtail.						
Late autumn, 1927	3.23	16.37	25.83	4.33	0.37	0.58
Early spring, 1928	5.02	24.90	19.32	5.00	0.65	0.73
Fine-leaved fescue.						
Late autumn, 1927	4.10	16.70	27.84	5.70	0.71	0.56
Early spring, 1928	6.54	17.90	21.40	5.20	0.77	0.64
Indigenous perennial rye-grass.						
Late autumn, 1927	1.87	15.77	22.24	6.15	0.32	0.53
Early spring, 1928	2.27	13.61	17.20	5.81	0.66	0.66
Indigenous cocksfoot.						
Late autumn, 1927	2.86	20.17	24.70	8.74	1.22	1.04
Early spring, 1928	4.16	14.61	17.33	6.25	0.72	1.18

and timothy, in which the contribution of the stem to the total produce was nearly as high as in Italian rye-grass, while in golden oat grass this was considerably higher, being 49 per cent. The stems of these grasses, however, were not grazed as hard as those of Italian rye-grass, and a comparison of the chemical composition of their stems as pasture becomes a matter of interest and importance.

TABLE VII.—*Yield (in lb.) of stem as pasture of Italian rye-grass, perennial rye-grass, timothy and golden oat grass from an area of* 1/100*th acre in season* 1927, *and the calculated percentage composition of the stem.*

Species.	Yield of dry matter.	Crude protein	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Italian rye-grass	23.8	9.70	21.33	6.34	0.65	0.62
Perennial rye-grass	19.5	10.66	26.19	6.21	0.76	0.43
Timothy	17.1	13.98	27.54	6.28	0.77	0.44
Golden oat grass	31.3	12.23	32.48	5.65	0.65	0.38

Examination of Table VII shows that in chemical composition fibre is the constituent in which the widest variations are to be found, and though there are doubtless other factors than fibre content that determine the palatability of the stems of grasses as pasture, it is rather significant to find that palatability in this particular case appears to be largely governed by the percentage of fibre. Thus the stems of the grasses were grazed by sheep in the order in which they appear in Table VII, and this, as will be seen, is in ascending order of fibre content.

The investigation, as already mentioned, extended over three seasons, and from the results obtained, that is yields of the grasses as pasture and hay and their mode of behaviour under the treatment they received, it is possible to classify the grasses into those best suited for pasture and hay respectively. It was found that indigenous cocksfoot, fine-leaved fescue and meadow foxtail are particularly well suited for both hay and pasture, while perennial rye-grass and the pasture types of timothy are better suited for pasture than for hay. Golden oat grass, on the other hand, gives excellent yields of hay of good quality, but is not well suited for pasture.

TABLE VIII.—*Total yield (in lb.) of dry matter for seasons* 1927, 1928 *and* 1929 *from an area of* 1/100*th acre of indigenous strains of cocksfoot, meadow foxtail and perennial rye-grass as pasture, together with the calculated percentage composition of the produce.*

Species.	Yield of dry matter.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Cocksfoot, indigenous	165.4	17.14	26.45	7.67	0.74	0.85
Meadow foxtail, indigenous ..	110.5	19.40	25.44	6.83	0.76	0.60
Perennial rye-grass, indigenous ..	129.3	15.33	27.00	7.71	0.84	0.70

On reference to Table VIII it is seen that the variation in yield of the indigenous strains of cocksfoot, meadow foxtail and perennial rye-grass as pasture, all of which grasses are particularly well suited for the purpose, is fairly wide, and of the three, meadow foxtail gives the lowest yield though the composition of its produce is superior to that of cocksfoot and perennial rye-grass. Thus the percentage of protein is higher and of crude fibre lower in meadow foxtail than in cocksfoot and perennial rye-grass, while its phosphoric acid content is approximately the average of the other two grasses.

When the yield and composition of a grass are satisfactory, one of the most important factors in determining its suitability for pasture is its persistency. Golden oat grass, as previously stated, in addition to producing excellent hay, gives in the first year pasture above the average in yield and composition, but its failure to withstand hard grazing in subsequent years renders it unsuitable for pasture. From Table VIII it is seen that over the three years cocksfoot gives the highest yield of dry matter as pasture, followed by perennial rye-grass, and although meadow foxtail is the lowest in yield, its produce is superior to the two other species in chemical composition.

TABLE IX.—*Yield (in lb.) of dry matter of two strains of two grasses as pasture from an area of* 1/100*th acre, and the calculated percentage chemical composition of their produce as pasture in* 1927.

Species and strain.	Yield of dry matter.	Crude protein.	Crude fibre.	Silica-free ash (SiO_2).	Phosphoric acid (P_2O_5).	Lime (CaO).
Cocksfoot, indigenous 1640 ..	80.6	14.51	28.90	8.31	0.75	0.76
Cocksfoot, indigenous 1163 ..	76.5	15.20	27.98	7.62	0.71	0.75
Perennial rye-grass 1412	67.5	14.74	26.82	7.55	0.86	0.71
Perennial rye-grass 1413	59.4	14.04	26.90	7.40	0.80	0.66

The yields and general characteristics of the grasses under investigation and their suitability for different purposes have already been dealt with, but it is necessary to draw attention to the fact that different strains of the same species of grass show fairly wide variation both in yield and chemical composition, as will be seen from Table IX.

Table IX shows that although there is a greater resemblance between the yield and chemical composition of the strains of the same grass than there is between the species, yet the difference between strains of the same species is quite appreciable. The yield of cocksfoot 1640 is greater than that of cocksfoot 1163, but the nutritive value of the produce of the latter is superior. Similar differences are to be seen in the yield and composition of the two strains of perennial rye-grass, and although the yield of perennial rye-grass 1412 is greater than that of 1413 (except for the slightly higher fibre content of the latter), it will be found to be weight for weight superior in nutritive value to 1412.

The whole experimental area received a basal dressing of phosphates and potash, and to a portion of the area nitrogenous manures were applied. The plots referred to as control are those to which phosphates and potash were applied, while the manured plots are those which in addition received nitrogenous manures.

The effect of the application of nitrogenous manures on the nitrogen content of the produce of the grasses has been to increase this in all cases, whether as pasture, hay or aftermath. In Table X the influence of the manure on the percentage of nitrogen in the pasture, hay and aftermath of three grasses is shown.

TABLE X.—*Percentage of nitrogen in the produce of the dry matter of three grasses as pasture, hay and aftermath from the control and manured plots.*

Species.	Produce.	Percentage of nitrogen.	
		Control.	Manured.
Timothy, Grinstad	Pasture	2.74	3.42
	Hay	1.20	1.92
	Aftermath	1.70	1.91
Fine-leaved fescue	Pasture	2.02	2.84
	Hay	0.80	1.26
	Aftermath	2.12	3.04
Italian rye-grass	Pasture	2.16	3.05
	Hay	0.91	1.20
	Aftermath	1.31	1.38

In the results shown in Table X the percentage of nitrogen in pasture has been calculated from the yield and chemical composition of the different samples taken during the grazing season. Examination of this table shows that the nitrogenous manures have in all cases increased the nitrogen content of the produce. On comparing the nitrogen content of the pasture of these grasses with the aftermath it will be noticed that in timothy and Italian rye-grass the pastures are higher than the aftermath, whereas in fine-leaved fescue the aftermath is higher than the pasture. This difference is accounted for by the aftermath of timothy and Italian rye-grass having a high ratio of stem to leaf, while in fine-leaved fescue this is extremely low. The influence of nitrogenous manures on the nitrogen content of the stem and leaf is to increase it in both as shown in Table XI.

TABLE XI.—*Percentage of nitrogen in the dry matter of the stem and leaf of the produce of two strains of perennial rye-grass from the control and manured plots.*

Strains.	Produce.	Percentage of nitrogen.			
		Control.		Manured.	
		Stem.	Leaf.	Stem.	Leaf.
Perennial rye-grass indigenous 1413 ..	Pasture ..	1.70	2.51	2.39	3.22
	Hay ..	0.92	0.93	1.12	1.82
	Aftermath ..	1.24	1.36	1.37	1.44
Perennial rye-grass commercial 1738 ..	Pasture ..	2.01	2.43	2.52	2.87
	Hay ..	0.64	0.70	1.46	2.13
	Aftermath ..	1.24	1.53	1.48	1.99

Generally speaking, it may be said that nitrogenous manures have a greater influence on the nitrogen content of the leaf than of the stem, though this is not without exception. For example, in the aftermath of the indigenous variety referred to in Table XI, and in the pasture of the commercial variety, the nitrogen content of the stem is increased to a greater extent than that of the leaf.

The difference in the effect of nitrogenous manures on the nitrogen content of pasture following pasture compared with pasture following hay is illustrated in Table XII.

TABLE XII.—*Percentage of nitrogen in the stem, leaf and pasture of perennial rye-grass when pasture follows pasture and when pasture follows hay.*

	Control.			Manured.		
	Stem.	Leaf.	Pasture.	Stem.	Leaf.	Pasture.
Percentage of nitrogen in pasture following pasture	1.99	2.61	2.48	2.09	2.90	2.65
Percentage of nitrogen in pasture following hay	1.92	2.68	2.45	2.83	3.12	2.98

On comparing the nitrogen content of the dry matter of the two control plots, it is seen that in their nitrogen content they are in close agreement, and, apart from the difference in yield, which as already mentioned is greater where pasture follows hay, there is very little difference in the crude protein content of the produce of the two pastures. When, however, nitrogenous manures are added the effect is certainly the same on the nitrogen content of both pastures, but their produce is not affected to the same extent. Thus the increase in the nitrogen content of the produce of the manured over the control is greater in the stem, leaf and total produce of the pasture following hay than it is in the pasture following pasture.

Previous investigations at Aberystwyth (Fagan and Provan 1930) have gone to show that the effect of nitrogenous manures on the phosphatic content of the mixed herbage of the pastures has been to depress this constituent. In the present investigation with individual grasses the effect has been similar with a number of grasses, though this is by no means the case with all, as shown in Table XIII.

TABLE XIII. *Showing the yield (in lb.) of dry matter and phosphoric acid contained in the produce as pasture of eighteen strains of grasses from an area of 1/100th acre.*

Species and strains.	Control.		Manured.	
	Yield of dry matter.	Yield of phosphoric acid (P_2O_5).	Yield of dry matter.	Yield of phosphoric acid (P_2O_5).
Cocksfoot, indigenous 1163	76.5	0.55	103.6	0.73
Cocksfoot, indigenous 1640	80.6	0.62	81.7	0.58
Cocksfoot, New Zealand	63.5	0.53	100.5	0.81
Cocksfoot, commercial	92.6	0.73	120.2	0.77
Meadow foxtail, indigenous	67.0	0.54	116.7	0.91
Meadow foxtail, commercial	44.7	0.32	87.8	0.58
Perennial rye-grass, indigenous 1413	59.4	0.48	109.0	0.84
Perennial rye-grass, Jædersk	44.8	0.38	84.7	0.68
Perennial rye-grass, indigenous 1412	67.5	0.58	113.0	0.86
Perennial rye-grass, commercial	66.7	0.56	122.0	0.98
Timothy, indigenous 309	55.4	0.40	83.8	0.63
Timothy, indigenous 310	58.9	0.45	95.7	0.76
Timothy, Grinstad	46.6	0.38	66.9	0.56
Timothy, commercial	39.7	0.32	60.1	0.46
Italian rye-grass, indigenous	61.5	0.46	94.4	0.84
Italian rye-grass, commercial	63.6	0.50	84.2	0.64
Golden oat grass	63.0	0.46	128.6	0.98
Fine-leaved fescue	82.6	0.57	105.7	0.75

As a result of the application of nitrogenous manures it will be seen from Table XIII that the yield of dry matter and of phosphoric acid is in all cases increased, though the phosphoric acid is not increased in all the grasses in proportion to the dry matter. Thus the phosphoric acid content of the first ten grasses and of the commercial varieties of timothy and Italian rye-grass referred to in Table X is found to be depressed when equal weights of produce from the control and manured plots are compared. The remaining grasses, however, when a similar comparison is made, show an increase in the phosphoric acid of the manured over the control plots.

The effect of nitrogenous manures on the phosphatic content of the stem and leaf of the pasture of one and the same grass is not always the same. This varying influence of nitrogenous manures is illustrated in Table XIV.

From Table XIV the yield of dry matter and phosphoric acid is seen to be increased in both stem and leaf as a result of the application of nitrogenous manures. But when equal weights of either the stem or leaf of the same grass from the control and manured plots are compared, the phosphoric acid content of these are not always similarly affected. For example, in indigenous meadow foxtail the phosphatic content is depressed in the leaf and increased in the stem, while in golden oat grass it is increased in the leaf and depressed in the stem. When the phosphoric acid content is depressed or increased in both the stem and leaf of a grass it is of course depressed or increased in its produce as pasture. But where it is increased in the stem and depressed in the leaf or *vice versa*, it depends upon the ratio of stem to leaf in the pasture what the effect of the manure is on the produce. This is well

TABLE XIV. *Showing the variation in effect of nitrogenous manures on the phosphatic content of the stem and leaf of individual strains of grasses as pasture.*

Species and strains.	Part of plant.	Control.		Manured.	
		Yield (in lb.) of dry matter.	Yield (in lb.) of phosphoric acid (P_2O_5).	Yield (in lb.) of dry matter.	Yield (in lb.) of phosphoric acid (P_2O_5).
Timothy, indigenous 310	Stem	15.7	0.11	28.5	0.22
	Leaf	43.2	0.34	67.2	0.54
Timothy, commercial 347	Stem	13.6	0.10	21.7	0.15
	Leaf	26.1	0.22	60.0	0.30
Meadow foxtail, indigenous ..	Stem	10.0	0.07	20.8	0.16
	Leaf	57.0	0.46	96.0	0.74
Golden oat grass	Stem	31.0	0.20	43.8	0.27
	Leaf	31.8	0.26	84.7	0.71

illustrated in indigenous meadow foxtail where the phosphoric acid is depressed in the leaf but increased in the stem. But the ratio of stem to leaf in the produce of the grass as pasture is 1 to 5.7 with the result that the ultimate effect of the nitrogenous manure on the phosphatic content of the produce is that it is depressed.

This variation in effect of nitrogenous manures on the phosphatic content of the stem and leaf is similar in the hay and aftermath of the grasses. Owing to the high proportion of stem in the hay of most grasses its effect on the stem determines its influence on the produce as hay. This effect of the manure is illustrated in Table XV.

TABLE XV. *Showing the variation in effect of nitrogenous manures on the phosphatic content of the stem and leaf of individual grasses as hay.*

Species.	Part of plant.	Control.		Manured.	
		Yield (in lb.) of dry matter.	Yield (in lb.) of phosphoric acid (P_2O_5).	Yield (in lb.) of dry matter.	Yield (in lb.) of phosphoric acid (P_2O_5).
Italian rye-grass	Stem	16.9	0.13	33.5	0.21
	Leaf	4.7	0.02	7.6	0.04
Timothy, commercial	Stem	10.4	0.06	12.4	0.07
	Leaf	4.0	0.02	3.8	0.02
Meadow foxtail indigenous ..	Stem	4.0	0.02	8.9	0.05
	Leaf	8.2	0.04	22.9	0.10

The yield of the stem and leaf of hay as of pasture is seen to be increased with the application of nitrogenous manure, and as a result of this the yield of

phosphoric acid also is increased. However, the phosphoric acid is not increased in proportion to the dry matter in all cases. Thus in the stem of Italian rye-grass it is decreased, while in the leaf it is increased, and as the stem in the hay is greatly in excess of the leaf the effect is that the phosphoric acid of the hay is depressed. In indigenous meadow foxtail the effect is reversed, that is, the phosphatic content of the stem is increased while that of the leaf is decreased, but as the hay of meadow foxtail contains twice the weight of leaf that it does of stem, the effect on the hay as a whole is to depress its phosphatic content.

Nitrogenous manures have on the whole a depressing effect on the lime content of the mixed herbage of our pastures (Fagan and Watkins 1932), though this is not as pronounced as on their phosphatic content. When, however, they are applied to individual grasses, the lime content of some is depressed while that of others is increased.

TABLE XVI. *Showing the yield (in lb.) of dry matter and lime contained in the produce as pasture of eighteen strains of grasses from an area of* 1/100*th acre.*

	Control.		Manured.	
	Yield of dry matter.	Yield of lime (CaO).	Yield of dry matter.	Yield of lime (CaO).
Cocksfoot, indigenous 1163	76.5	0.50	103.6	0.66
Cocksfoot, indigenous 1640	80.6	0.62	81.7	0.63
Cocksfoot, New Zealand	63.5	0.42	100.5	0.59
Cocksfoot, commercial	92.6	0.55	120.2	0.67
Meadow foxtail, indigenous	67.0	0.37	116.7	0.67
Meadow foxtail, commercial	44.7	0.25	87.8	0.45
Perennial rye-grass, indigenous 1413 ..	59.4	0.39	109.0	0.76
Perennial rye-grass, Jædersk	44.8	0.35	84.7	0.64
Perennial rye-grass, indigenous 1412	67.5	0.48	113.0	0.69
Perennial rye-grass, commercial	66.7	0.46	122.0	0.84
Timothy, indigenous 309	55.4	0.34	83.8	0.54
Timothy, indigenous 310	58.9	0.37	95.7	0.59
Timothy, Grinstad	46.6	0.32	66.9	0.44
Timothy, commercial	39.7	0.25	60.1	0.36
Italian rye-grass, indigenous	61.5	0.54	94.4	0.73
Italian rye-grass, commercial	63.6	0.49	84.2	0.75
Golden oat grass	63.0	0.40	128.6	0.85
Fine-leaved fescue	82.6	0.57	105.7	0.60

The total weight of lime in the produce of the manured plots, as was the case with phosphoric acid, is greater than that in the produce from the control, but this is not increased in all the grasses in proportion to the increase in dry matter. Thus in all strains of timothy it is depressed with the exception of timothy 309 in which it is increased. Again, if perennial rye-grass is taken, it is depressed in Jædersk and in indigenous strain 1412, whereas it is increased in indigenous strain 1413 and unaffected in the commercial variety.

In the pasture of the eighteen strains of grasses under investigation the lime content of ten is depressed, that of seven is increased, and of one is unaffected, as the result of the application of nitrogenous manures.

The lime content of the stem and leaf of the same grass as pasture is not always affected in the same direction by the addition of nitrogenous manures, that is, it may be increased in the stem and decreased in the leaf, and *vice versa*.

Previous work at Aberystwyth has shown that the leaf of a grass is richer in lime than the stem, so that in those grasses where the proportion of leaf to stem in

the produce is high, and the application of nitrogenous manures increases the lime content of the leaf, it naturally follows that the lime content of the total produce of the grass as pasture is increased. This effect is much more evident in the aftermath than in the pasture of these grasses, and without exception it may be said that when the lime content of the leaf of the aftermath is depressed or increased as the result of the application of nitrogenous manures the total produce is similarly affected. In the aftermath of the grasses under investigation thirteen of the seventeen had their lime content depressed as the result of the application of nitrogenous manures.

The lime content of fifty per cent. of these grasses as hay was depressed, while that of the remainder was increased on the addition of nitrogenous manures. The stem and leaf of the same grass as hay are not in all cases affected in a similar manner by the manure, and owing to the high proportion of stem to leaf in the majority of hays the ultimate effect of the manure on the total produce is to a large extent dependent upon its effect on the stem.

The general conclusions that may be drawn from the results of this investigation on the chemical composition of individual grasses, are, that :—

(1) The total yield of dry matter of each grass whether as pasture, hay or aftermath is increased as the result of the application of nitrogenous manures.

(2) The greatest amount of nutrients whether as pasture, hay or aftermath is not always given by the grass showing the heaviest yield.

(3) The ratio of stem to leaf in the produce has a considerable influence on its composition, for the leaf is higher in protein and lime and lower in fibre content than the stem.

(4) Taking grasses as a whole the leaf portion is generally better grazed than the stem. However, the stem of some grasses is much better grazed than others, and the palatability of these stems appears to be largely governed by the percentage of fibre they contain.

(5) Certain grasses are found to be better suited for pasture than for hay, others better for hay than pasture, while some are suited for both hay and pasture.

(6) The nitrogen content of all grasses, whether as pasture, hay or aftermath, is increased as the result of the application of nitrogenous manures, and generally speaking it may be said that this effect is greater on the leaf than on the stem, though this is not without exception.

(7) The phosphoric acid content is in the large majority of grasses depressed as a result of the application of nitrogenous manures. The influence of the manure on the phosphatic content of the stem and leaf of the same grass is not always in the same direction. Thus in some grasses it increases that of the leaf and decreases that of the stem or *vice versa*.

(8) The effect of the manure on the lime content of the grasses is not as definite as it is on their phosphatic content, though in the majority of the grasses under investigation it is depressed. Again the lime content of the stem and leaf of the same grass is not always influenced in the same direction, for it may be increased in one and depressed in the other or *vice versa*.

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VARIATIONS IN THE WEIGHT OF SHEEP: A NOTE AS TO PROCEDURE.

BY

LL. IORWERTH JONES, B.Sc.

In connection with the earlier experiments conducted at the Station, it was noticed that the weight of a sheep varies from time to time during the day, according to the amount of food eaten just previous to the weighing. It was then found that if the sheep were brought off the pasture at the same time of day and immediately weighed, the variation from day to day was considerably reduced. However, it was further noticed that on occasions these weights were also subject to wide variations —governed chiefly by the weather conditions of the previous night—and it was considered that if the sheep were placed under cover and fasted overnight more reliable results would by that means be obtained. With the object of testing this point, 50 sheep were weighed on four consecutive days under the two systems, namely, (a) after a 16 hours' overnight fast under cover, and (b) when taken direct from the pasture at 10 a.m. on each day.

The weights obtained were tabulated in each case, and the mean for each sheep together with the variation from the mean, expressed as the number of departures in terms of a unit of ¼ lb. were obtained for the two methods of weighing. The results given below show the number of weights which coincided with the mean, the number which differed from the mean by one ¼ lb., by two ¼ lb., by three ¼ lb., etc. for the two methods of weighing respectively.

Amount of variation from mean expressed as ¼ lb.	*Number of cases.* "*Fasted.*"		"*Off-pasture.*"	
0	20		20	
+ 1	31	81	21	60
— 1	30		19	
+ 2	10		17	
— 2	20	71	27	68
+ 3	20		14	
— 3	21		10	
+ 4 to + 6	20	39	25	48
— 4 to — 6	19		23	
Over + 6	5	9	14	24
,, — 6	4		10	

If we compare the figures set out above it will be seen that (1) 40.5 per cent. of the weights are within 3/8th lb. of the mean weight when the sheep were fasted, while only 30 per cent. were within that latitude when the sheep were weighed direct off the pasture; (2) 24 per cent. of the readings vary by more than 7/8th lb. from the mean in the case of the fasted sheep, whilst 36 per cent. vary by more than this margin in the case of the sheep taken direct from the pasture; (3) only

4½ per cent. of cases in respect of the fasted sheep vary by more than 1 5/8th lb., whilst 12 per cent. of readings in respect of the sheep weighed off the pasture are within that region.

These data therefore show that the weights obtained on the fasted sheep are nearer the mean weight than are those obtained on the ex-pasture sheep. The latter weights are considerably scattered from the mean and thus give rise to a more considerable experimental error than do the weights obtained after an overnight period of fasting.

As the result of these preliminary weighings it was decided to adopt the procedure outlined for fasting ; and as far as possible to conduct all critical sheep weighings on this basis. In the experiments described in the following article the critical and final weights were always obtained after fasting, and when possible all intermediate weights were also obtained by adopting the same procedure.

PRELIMINARY EXPERIMENT TO TEST THE REACTION OF SHEEP (LIVE WEIGHT INCREASE) TO DIFFERENT SPECIES AND STRAINS OF GRASSES AND CLOVERS AND TO TEST THE YIELD AND OTHER CHARACTERS OF THE SPECIES AS SUCH.

BY

LL. IORWERTH JONES, B.Sc.

(With One Plate and Five Text-figures).

INTRODUCTION.

Great difficulty presents itself when it is desired to test the reaction of animals to different species and strains of grasses.

It is only possible to test carrying capacity and live weight increase when enough seed is available to put down plots of considerable size. With a view to obtaining some preliminary data on these lines it was decided in 1928 to resort to the use of tethered sheep. It was thought that by this means evidence, which might at least be highly suggestive, could be obtained from comparatively small plots. The aim in the first instance was, however, as much to develop a technique and a sound method of dealing with tethered sheep as to obtain data from the sheep themselves. The results discussed in this paper are the first that have been obtained at the Station by the use of the tethered animal. This procedure is now largely superseding that described in a previous article, while the use of shears and the lawn mower, except as a means of taking samples in connection with the tethered animal, has also been discontinued except in a few special cases.*

MATERIAL AND METHODS.

Lay out. On May 17th, 1928, an area of ground 1½ acres in size on Penglais Field was sown out in four plots as follows :—

Plot 1. Wild white clover at 14 lb. per acre.

Plot 2. A mixture of grasses and clovers :

Italian rye-grass	20 lb. per acre.
Perennial rye-grass (Indigenous from Kentish wild white clover pastures)	17 lb. ,,
Rough-stalked meadow grass	10 lb. ,,
Wild white clover	4 lb. ,,

Plot 3. Ordinary commercial cocksfoot at 42 lb. per acre.

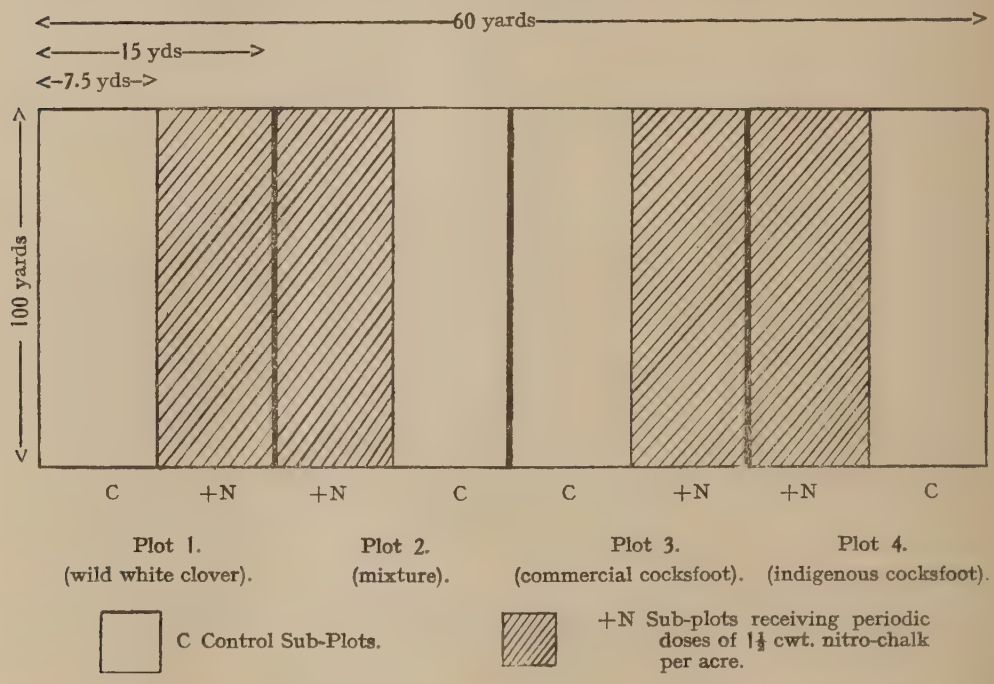
Plot 4. Indigenous cocksfoot at 42 lb. per acre (a mixture of Bc. 1163 and Bc. 1162.)

The heavy seedings were resorted to with the object of securing a good " take " and excluding as far as possible the influence of unsown grasses and weeds. The

*The tethered sheep afford an excellent means of conducting experiments relative to the biotic factor, and a number of experiments are now being conducted on pastures of different types and on developing swards from seeds mixtures to ascertain the effect of differential grazing.

plots were sown without a nurse crop and were grazed lightly during the summer and autumn with a view to obtaining a well-established sward. The grazing of the mixture and commercial cocksfoot plots was commenced on July 25th—10 weeks after sowing—whilst the indigenous cocksfoot and wild white clover were first grazed on August 17th—13 weeks after sowing. In each case the plots were grazed by one pair of tethered lambs.

In the early spring of 1929 it was decided to test the influence of a nitrogenous fertilizer in connection with the experiment. Consequently each plot was divided longitudinally into two equal parts, one of which received dressings of nitro-chalk, whilst the other served as control. The plan of the experiment is shown in Text-fig. 1.



Text-fig. 1. Plan of the experiment.

Manuring. The whole area received a dressing of 6 cwt. of slag (38 per cent. phosphate) in March, 1928, and 4 cwt. of slag (35 per cent. phosphate) in April, 1930, or a total of 10 cwt.—equivalent to 8 cwt. of slag per acre.

The nitrogenous manure was applied as three dressings of nitro-chalk per year for the first two years (1929 and 1930) and one dressing in 1931. Each dressing consisted of 1½ cwt. of nitro-chalk per acre. The dates of applying the manure were as follows :—

	First.	*Second.*	*Third.*
1929	January 30th.	End of May.	End of July.
1930	March 7th.	Middle of July.	Middle of September.
1931	March 6th.	—	—

The first dressing of nitro-chalk in every year was applied in one day, but during the grazing season this was impossible owing to the presence of sheep, and thus it had to be drawn out over a period of four or five days—the areas on which the sheep had just finished grazing being manured as they became free.

The control of the sheep. The sheep were tethered in pairs.* The main chain was 10½ feet long and bifurcated at a swivel into two separate chains each of 1½ feet, and the end of each of these was attached to one of the sheep by means of a metal collar.

One pair of tethered sheep was made responsible for each plot. The width of the plot was 7½ yards, and the length of the tether chains was so arranged that the sheep could just graze both edges of the plot when the end of the chain was pegged in the middle of the plot. Each pair was started at the bottom. At the beginning of the experiment they were shifted 4 yards upwards along the plot every morning, but it was soon found that this did not result in uniform grazing, the sheep having a strong tendency to give the greatest attention to the periphery of the circle and at the same time to foul the centre area. Consequently, on July 1st, 1929, the system was modified, and since then each pair of sheep has been shifted about 2 yards every morning and evening ; this has resulted in much more uniform grazing. This method of management gave a good system of rotational grazing with a three-weekly period of rest between successive grazings. At any particular time the sheep had access to an area a part of which consisted of fresh grass and a part of grass on which they had already spent some hours. The experiment was conducted for three grazing seasons. Grazing was started in April or early May each year and continued until the end of October.

The plots were lightly grazed over once or twice during the late autumn or winter as seemed necessary, and at the same time yield data were obtained and the number of sheep days recorded.†

The manner in which the sheep were tethered on the plots is illustrated by Plate III.

The selection, grouping and weighing of the sheep. With the exception of a period of three weeks in July, 1930, when young weaned lambs were used, the sheep employed were yearlings. The lambs proved unsatisfactory as some of them suffered from the cold wet weather prevailing at that time, and it was considered best to use yearlings all through the experiment. The sheep were grouped in pairs so that the weight of each pair was practically identical. In order to achieve proper pairings 16 of the most uniform sheep, as judged by the eye and by weight, were selected from the flock for the experiment. The largest, the smallest and any that showed signs of being unhealthy were discarded. The selected sheep were weighed on three consecutive mornings after a fasting period of 16 hours in each case. They were then arranged in descending order of weight, and when pairing the lightest was placed with the heaviest all down the scale till the pairs were made up. The average initial weight of the sheep employed was about 50 lb.

During 1931 it was found impossible to obtain 16 uniform sheep of similar breed, and in this year 8 pure bred Kerry Hill sheep were used together with 8 Welsh mountain yearlings. One of each of these breeds was placed in every pair ; the heaviest of one group being partnered by the lightest of the other group.

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*The tether chains used were similar to those employed in ordinary farm practice in parts of Sweden, and were obtained from Mr. Joh. P. Johansson, Anderslöf, Sweden.

†The number of sheep days were recorded for the whole area and these days were allocated to the several plots in proportion to the yield of herbage which each produced.

Each plot was stocked with one pair of sheep, and as it was fully realised that the experimental error in using such a small number of sheep must be relatively high, efforts were made to reduce this as far as might be possible by adopting the following precautions :—

(a) It is well known that some animals improve at a much faster rate than others, and the only way of eliminating this error is by using a sufficiently large number of sheep. In this experiment the area available, however, was strictly limited, and it was impossible to place more than one pair on each sub-plot at a time. In 1930 and 1931 the grazing season was divided into two periods, a new lot of sheep being introduced for the second period. Thus during the three years of the experiment, each plot has been grazed by 5 pairs of sheep.

(b) Preliminary tests were made relative to the daily variation in the weight of sheep. The data have been presented in the immediately preceding article, and as a result of these tests it was decided to employ the method of fasting therein described in arriving at the initial and final weights of the sheep. In addition to these initial and final weighings the sheep were also weighed on their plots about once a fortnight. This gave an indication of the progress of the sheep and it was also thought that it would give some indication of the increase in weight produced should a particular sheep die during the experiment.

Methods of sampling. In order to ascertain the bulk of herbage produced on each plot and to make an accurate botanical analysis of the produce, it was necessary to conduct a proper system of sampling throughout the season.

In 1929 and 1930 the sampling consisted of five one-foot quadrats cut in both pre-grazing and post-grazing areas. In 1931 it consisted of three one-yard samples in each case. The grass cut on these areas was placed in skrim bags to dry and then weighed : the difference in weight between the pre-grazing and post-grazing cuts represented the amount eaten off a known area. This two-fold system of sampling was carried out weekly on all the plots and the average difference for the whole year between the pre- and post-grazing sample was obtained. This gave the average amount eaten by the sheep off a known unit of area for each grazing and for each plot, which was then calculated as lb. per acre. The yield for the whole season was found by multiplying this average figure (lb. per acre) by the number of grazings on each plot. Further, the pre- and post-grazing samples were separated into the various species, so that it was possible to calculate in addition to the total amount eaten, the amount of clover, cocksfoot and other individual species that was eaten.

The actual cutting of the samples was done by means of sheep shears in 1929 and 1930, while in 1931 a special four-blade clipper was employed. In addition to taking cut samples of the produce, counts of plants per unit of area were made *in situ* on the plots early in the experiment, and by lifting sample turfs (6 in. × 6 in.) at the end of the experiment.

DISCUSSION OF RESULTS.

The data collected in connection with this experiment can be most conveniently dealt with under a number of appropriate headings. The botanical and yield data will be discussed before referring to the live-weight increase of the sheep, and the carrying capacity of the swards.

BOTANICAL COMPOSITION AND PERSISTENCY.

During the first winter (January, 1929) counts of plants per unit of area were made on the four plots. This was done before any differential manuring of the

plots had been begun. The results are shown in Table I, from which it is seen that there was a good take on all plots, and, further, that the number of plants per unit of area on the two cocksfoot plots was very similar, there being less than 2 per cent. difference in favour of the indigenous plot. Both the cocksfoot plots and the mixtures were remarkably free from unsown species or weeds, but the wild white clover plot, in spite of the fact that it also had a very good take, had in addition a high percentage of unsown species, chiefly clumps of Italian rye-grass and a large number of small plants of bent and *Poa annua*. The Italian rye-grass clumps were pulled up by hand, thus leaving a sward composed of wild white clover mainly, together with appreciable amounts of bent and *Poa annua*.

TABLE I.—*Showing the average number of plants of the sown species per square foot during the first winter* (*January*, 1929).

Plot 1.	Wild White clover		89.3
Plot 2.	Mixture :		
	Perennial rye-grass	51.0	
	Italian rye-grass	15.5	
	Rough-sta'ked meadow grass	16.0	95.0
	White clover	12.5	
Plot 3.	Commercial cocksfoot		74.8
Plot 4.	Indigenous cocksfoot		76.2

Further analysis of these plots was made at the commencement and at the end of the third grazing period—in February and December, 1931. Turfs 6 in. × 6 in. were taken from each plot and all tillers of plants were counted ; the results are shown in detail in Appendix Table I, whilst the more interesting points are shown in the tables which follow.

The percentage composition of the four plots during the third year of the experiment is shown in Table II. From this table it is seen that in the mixture

TABLE II.—*Showing the average percentage botanical composition of the four plots during the third grazing season. Tillers per unit of area.*

Species.	Wild white clover Plot 1	Mixture. Plot 2.	Commercial cocksfoot Plot 3.	Indigenous cocksfoot Plot 4.
Perennial rye-grass	—	**51.5**	—	—
Cocksfoot	—	—	**5.5**	**32.0**
White clover	**19.6***	**9.6**	6.5	4.8
Rough-sta'ked meadow grass ..	25.1	**27.3**	38.2	34.4
Poa annua	39.4	5.5	8.6	9.0
Bent	14.5	3.8	25.9	9.0
Yorkshire fog	1.0	1.4	11.6	9.2
Other weed grasses	Trace	0.6	2.4	0.8
Weeds	0.4	0.3	1.3	0.8
Moss	14.5	5.0	57.0	21.5

*Figures in heavy type indicate sown species.

(Plot 2) the pasture was still largely composed of sown species, viz. 88.4 per cent., whilst on the other three plots, weeds and unsown species took by far the most

prominent position. Thus, indigenous cocksfoot contributed 32 per cent. to its plot; wild white clover 19.6 per cent. to its plot, and commercial cocksfoot only 5.5 per cent. to its plot. In these three plots (pure species) the pasture by the third year is seen to consist very largely of bent, Yorkshire fog, *Poa annua* and unsown rough-stalked meadow grass.

Another interesting point is that there was more rough-stalked meadow grass in the cocksfoot plots where it had not been sown than there was in the mixture plot where it had been sown. This is probably due partly to the rye-grass in the mixture being more persistent than the cocksfoot in the pure plot, and partly to the fact that the cocksfoot makes an open sward with ample room for the development of rough-stalked meadow grass.

In addition to the counting of tillers of grasses and weeds, estimations (0 – 10) were made of the amount of moss present on each plot. These figures are given in Table II, and show that both cocksfoot plots have relatively high amounts of moss, that of commercial cocksfoot being extremely high, with more than 2½ times as much as the indigenous cocksfoot. On the other hand, plots sown with wild white clover have much less moss, the amount on the mixture plot being practically negligible—only 1/10th of the amount present on the commercial cocksfoot plot.

In comparing the pasture produced by the two strains of cocksfoot (see Table III), the main point that stands out is the much greater persistency of the

TABLE III.—*To compare the pasture produced in the third year by sowing ordinary commercial cocksfoot with that of indigenous cocksfoot. Expressed as number of tillers per square foot.*

Species.	Indigenous cocksfoot.	Commercial cocksfoot.	Commercial cocksfoot expressed as percentage of indigenous cocksfoot.
Sown.			
Cocksfoot	388	77	20
Unsown.			
Miscellaneous weeds	9	18	200
Bent	108	364	336
Wild white clover.	58	91	157
Rough-stalked meadow grass	406	540	133
Yorkshire fog	132	164	124
Total of unsown grasses and clovers	830	1333	160
Moss content of pasture*	21.5	57	265

*Figures for moss estimated on 0—10 basis.

indigenous strain, with the result that it offers less scope for unsown species to establish themselves in the sward. This is shown in the smaller amounts of bent, rough-stalked meadow grass, wild white clover, Yorkshire fog, miscellaneous weeds and moss in the indigenous than in the commercial cocksfoot pasture. The suppression of wild white clover by the indigenous cocksfoot is a matter of considerable consequence and, as will be shown, reacts adversely upon the herbage produced.

THE INFLUENCE OF NITRO-CHALK ON BOTANICAL COMPOSITION.

An interesting point in this experiment is the difference in botanical composition between the pastures which have received the dressings of nitro-chalk

and those which have not received any nitrogenous fertilizer. The main differences are shown in Table IV, where the percentage increase or decrease in the number

TABLE IV.—*To compare the effect of nitro-chalk on the average botanical composition of the four plots. Expressed as the number of tillers per square foot.*

Species.	Control plots.	+Nitrogen plots.	Per cent. increase due to nitrogenous fertilizer.
Moss	16	8.5	—47
Miscellaneous weeds	11	7	—36
Wild white clover	143	110	—23
Bent	197	151	—23
Poa annua	214	175	—18
Perennial rye-grass	672	604	—10
Yorkshire fog	85	78	— 8
Cocksfoot	227	238	4
Rough-stalked meadow grass	254	539	121
Total number of tillers of all species	1200	1342	12

of tillers, due to the application of the nitrogenous fertilizer, is given. The figures in the table indicate that the nitrogenous manure has

(*a*) reduced to a very marked extent the amount of moss, miscellaneous weeds, white clover, bent and *Poa annua* ;

(*b*) reduced to a lesser extent the number of tillers of perennial rye-grass and Yorkshire fog ;

(*c*) hardly affected the number of tillers of cocksfoot ;

(*d*) more than doubled the amount of rough-stalked meadow grass in the pasture, and

(*e*) increased the total number of tillers of all species per unit of area.

It is thus apparent that the various plants have reacted differentially to the application of the nitrogenous fertilizer, some being increased, whilst most of them have been decreased. Further, the extent of the increase or decrease of some of the plants depends on the nature of the other components of the pasture. This is particularly striking in the case of wild white clover. It has been shown that on an average of the four plots the nitrogenous fertilizer has suppressed the wild white clover to the extent of 23 per cent. If, however, we consider the plots individually (see Table V) it is seen that the nitrogenous manure has not affected the number

TABLE V.—*To compare the effect of nitro-chalk on the amount of wild white clover in each individual plot. Expressed as tillers per square foot.*

	Control plots.	+Nitrogen plots.	Per cent. decrease due to nitrogenous fertilizer.
Plot 1. Wild white clover	236	240	1.5 (increase)
Plot 2. Mixture	140	98	30.0
Plot 3. Commercial cocksfoot	112	70	37.5
Plot 4. Indigenous cocksfoot	84	32	61.9

of plants of wild white clover on Plot 1, where this species was sown alone, while on the other three plots it has suffered considerably. The most striking suppression of wild white clover under the influence of nitrogen, however, occurs on the indigenous cocksfoot plot (Plot 4) where the fertilizer has reduced the clover by over 62 per cent., while on the commercial cocksfoot plot and on the mixture plot it has been suppressed to the extent of 37.5 per cent. and 30 per cent. respectively. It would, therefore, appear from these results that the decrease in wild white clover following the application of nitro-chalk is due primarily to the keen competition set up by the more aggressive grasses, which under nitrogen make rapid and vigorous growth.

It is to be observed that there is a certain similarity in the effect of wild white clover and of nitro-chalk on the botanical composition of the pasture, while it is also to be noted that the influence of the fertilizer was more pronounced on the cocksfoot plots, which had a lower clover content, than on the two plots (the mixture and the wild white clover plots) which had a high percentage of clover. These results are shown in Table VI, where Plots 1 and 2 represent the wild white clover and mixture plots respectively, and Plots 3 and 4 represent the cocksfoot plots, which were not sown with any wild white clover. The main points brought out by the figures are as follows :

(a) The nitrogenous manure had no appreciable effect on the bent in the clover plots (Plots 1 and 2), but reduced it by 33 per cent. in the non-clover plots.

TABLE VI.—*To compare the effect of wild white clover and of the application of the nitrogenous manure on the pasture. Data in terms of tillers per unit of area.*

Species.	Plot.	Control.	+Nitrogen.	Per cent. increase due to nitrogenous fertilizer.
Bent	Plots 1 and 2.	110	114	+ 4
	Plots 3 and 4.	284	188	— 33
Rough-stalked meadow grass	Plots 1 and 2.	240	404	+ 68
	Plots 3 and 4.	272	674	+148
Miscellaneous weeds ..	Plots 1 and 2.	4	5	+ 25
	Plots 3 and 4.	18	9	— 50
Moss	Plots 1 and 2.	6	4	— 33
	Plots 3 and 4.	26	13	— 50

(b) Rough-stalked meadow grass shows an increase in number of tillers on all areas where the nitro-chalk was applied, but this is far more marked in the plots which have relatively little white clover present (the cocksfoot plots) where it has increased to $2\frac{1}{2}$ times the amount present on the control plots. It would appear from the above results that rough-stalked meadow grass demands a high nitrogen content in the soil. In the mixture and wild white clover plots this nitrogen was supplied by the clover present, and thus the addition of the nitrogenous manure which decreased the amount of clover in the mixture (Plot 2) has not had nearly such a marked effect as on the cocksfoot plots (Plots 3 and 4), which have been relatively low in wild white clover and consequently low in nitrogen except where it was supplied as nitro-chalk.

(c) In the case of miscellaneous weeds, the nitrogenous manure has halved the number of weeds on the non-clover plots (Plots 3 and 4). There has been no effect in the mixture plot (Plot 2) but in the wild white clover plot (Plot 1) there has been an increase in the number of weeds where the nitrogenous manure was applied.

(d) The moss content was reduced by 33 per cent. on the clover plots (Plots 1 and 2) and by 50 per cent. on the cocksfoot or non-clover plots (Plots 3 and 4).

The actual effect of a nitrogenous manure on the different species of grass is undoubtedly influenced to a considerable degree by the growth form of the species concerned. Cocksfoot to a marked degree, and perennial rye-grass to a considerable extent, are of upright growth and are easily accessible to the sheep. Consequently, any increase in the number of tillers which may tend to be brought about by the application of a nitrogenous fertilizer will be likely to be negatived from the point of view of the persistency of these grasses by the harder and earlier grazing (relative to the no-nitrogen plots) to which they would be subjected. Rough-stalked meadow grass, on the other hand, is not so easily accessible to sheep as the rye-grass and cocksfoot, and thus, granted that the competition with the top grasses is not too severe, it benefits much more by the application of the nitrogenous manure. It is also probable that the increased growth produced by the application of the manure sets up a keener general competitive influence which has had a marked adverse effect on most of the bottom species, *e.g.* bent, white clover, moss and weeds.

YIELD OF HERBAGE.

The data as to yield of herbage (sown and unsown species including grasses, clovers and weeds) are set out in Table VII.

It is not legitimate to compare the yields for 1929 and 1930 with those for 1931 because of the different methods of sampling that were adopted in the latter year. It is of considerable interest to note, however, that the yields in 1929, although representing the first harvest year, were in all cases lower than those for the second harvest year (1930). This was undoubtedly due to the fact that the former was a year of relative drought, and is in accord with the results discussed in the previous article. The figures in the table as a whole hold perfectly good for comparing the behaviour of the several plots within any one year, and this is the matter of chief interest.

TABLE VII.—*Showing the gross yield of herbage (grass, clover and miscellaneous herbs) per year on each plot. Expressed as lb. per acre.*

Year.	Plot 1. Wild white clover.	Plot 2. Mixture.	Plot 3. Commercial cocksfoot.	Plot 4. Indigenous cocksfoot.	Average of all plots.
1929	3052	3117	2605	2068	2711
1930	4310	3682	2625	2982	3400
1931	6920	7840	5218	5080	6265
TOTAL ..	14,282	14,639	10,451	10,130	12,376

The figures in the table show clearly that within any one year the plots in which white clover was sown (Plots 1 and 2) have given an altogether higher yield than have those sown with the grasses only (the cocksfoot plots).

The increase in yield of herbage produced by the application of the nitrogenous manure (see Table VIII) was more pronounced in the first than in the second year,

and far less pronounced in the third year. In the third year, however, the plots received only one dressing of nitro-chalk as compared with three dressings in 1929 and 1930, and this probably explains why the nitrogen plots fell so low during 1931. The falling off in the effect of nitrogen in the second harvest year is of considerable interest, and the more so since this is in complete agreement with the results discussed earlier in this *Bulletin*. If the plots are placed in two groups—(a) Plots 1 and 2, in which wild white clover had been sown and formed a high percentage of the sward, and (b) Plots 3 and 4, in which no wild white clover had been sown and which were relatively poor in clover content, especially during the first two years, it will be found that the nitrogenous manure has increased the yield far more on the non-clovery plots (Plots 3 and 4) than on the clovery plots (Plots 1 and 2); in fact it depressed the yield on the simple mixture plot (Plot 2) in the third year. Taking the total of the clovery plots (Plots 1 and 2) for the three years, the nitrogenous manure has increased the yield of herbage by 667 lb., while on the non-clovery plots (Plots 3 and 4) the manure has increased the total herbage for the three years by 2,868 lb., which is about 4½ times as much as the increase on the clovery plots.

TABLE VIII.—*Showing the effect of the nitrogenous fertilizer on the gross yield of herbage in the different years. Expressed as lb. per acre.*

	Year.	+Nitrogen.	Control.	Increase due to nitrogen.
Average of all plots	1929	3,109	2,313	796
	1930	3,750	3,050	700
	1931	6,400	6,130	270
	Total	13,259	11,493	1,766
Average of Plots 1 and 2. (Wild white clover and mixture plots.)	1929	3,374	2,795	579
	1930	4,152	3,840	312
	1931	7,268	7,492	—224
	Total	14,794	14,127	667
Average of Plots 3 and 4. (Cocksfoot plots.)	1929	2,845	1,831	1,014
	1930	3,348	2,259	1,089
	1931	5,532	4,767	765
	Total	11,725	8,857	2,868

Table IX shows the yield of the plots receiving the nitrogenous fertilizer expressed as a percentage of the yield on the areas which have had none. It shows that the cocksfoot plots increased their yield by 55 per cent. under the influence of the nitrogenous manure in 1929, while in the same year the mixture and wild white clover plots increased their productivity by only 21 per cent. when similarly treated. In 1930 the increases were 48 per cent. and 8 per cent. respectively, and in 1931 the comparable figures were given by an increase of 16 per cent. and a decrease of 3 per cent.

If we take the total for the three years we find that the nitrogenous manure increased the bulk of herbage on the cocksfoot plots by 32.5 per cent. and on the two plots containing high amounts of wild white clover by only 5 per cent.

The above results are decidedly important, and are of added significance when taken in conjunction with the findings from earlier trials. Thus, as in the case of the experiments discussed in the first article in this *Bulletin*, it is seen that

TABLE IX.—*Showing the yield of the plots receiving the nitrogenous fertilizer expressed as a percentage of the yield on the control plots.*

Year.	Average of all plots. Per cent.	Average of Plots 1 and 2. (Wild white clover and mixture plots.) Per cent.	Average of Plots 3 and 4. (Cocksfoot plots.) Per cent.
1929	135	121	155
1930	123	108	148
1931	104	97	116
Average	115	105	132

relatively speaking nitrogen appears to give its best result in a dry year. This is a fact which is certainly not generally appreciated—indeed the advice is not infrequently given to farmers that nitrogen should be explicitly withheld during dry springs. The small response due to nitrogen on the clovery plots is parallelled by the results discussed by Stapledon and Thomas (1930), who showed that on temporary leys with a high clover content the increased yield due to added nitrogen was not considerable.

THE INFLUENCE OF NITRO-CHALK ON THE YIELD OF WILD WHITE CLOVER.

The effect of the nitrogenous fertilizer on the yield of wild white clover as such is shown in Table X. Examination of the data indicates that the fertilizer has reduced the yield of clover on all plots. The extent of the suppression, however, varies from plot to plot, the least effect, namely, 9 per cent., being found on the plot sown with wild white clover only (Plot 1), which in addition to the white clover consists mainly of rough-stalked meadow grass, *Poa annua* and bent; this pasture in fact being devoid of quick-growing and aggressive grasses.

The commercial cocksfoot plot (Plot 3) by the third year was somewhat similar to the wild white clover plot (Plot 1). On the former plot the cocksfoot had to a large extent died out (only contributing 5.5 per cent. to the herbage on the tiller basis, see Table II) its place having been taken by wild white clover and re-

TABLE X.—*Showing the total yield of wild white clover in the various plots during the three years. Yield expressed as lb. per acre.*

Species.	+Nitrogen.	Control.	Per cent. decrease on nitrogen plots.
Cocksfoot: indigenous (Plot 4)	198	762	74
Cocksfoot: commercial (Plot 3)	875	993	12
Mixture (Plot 2)	1,619	2,859	44
Wild white clover (Plot 1)	4,246	4,655	9

latively non-aggressive grasses. On the latter plot the relatively non-aggressive grasses had come in and to a very appreciable extent taken the place of the clover.

On the cocksfoot plot, however, the nitrogenous fertilizer had decreased the white clover by 12 per cent. (on the basis of the yields over the three years) compared with a 9 per cent. decrease on the white clover plot. This result would have been due to the depressing effect of the nitrogenized cocksfoot during the earlier years. On the mixture plot (Plot 2) and the indigenous cocksfoot plot (Plot 4) there was a considerable amount of aggressive-growing grass in the herbage during the whole three years of the experiment (there being in the third year, on the tiller basis, 32 per cent. of cocksfoot on the indigenous cocksfoot plot and 51 per cent. of perennial rye-grass on the mixture plot), and consequently it is not surprising to find the yield of clover (over the three-year period) reduced by 44 per cent. under the influence of nitrogen on the mixture plot and by 74 per cent. on the indigenous cocksfoot plot.

This evidence, like that given by the tiller counts, adds support to the view that the suppression of the clover is not due to the direct action of the nitrogenous manure, since the plots devoid of aggressive grasses show only to a slight extent the suppression of clover, but rather to competition, the nitrogenous manures stimulating to further growth the aggressive species already present in the pasture.

THE INFLUENCE OF NITRO-CHALK ON THE YIELD OF GRASSES.

Table XI shows the effect of the nitrogenous fertilizer on the yield of grass as such (sown and unsown species)—clover excluded.

TABLE XI.—*Showing the effect of the nitrogenous fertilizer on the yield of grass (sown + unsown species)—excluding clover. Expressed as lb. per acre. Aggregate yields for the three years.*

Plots.	+Nitrogen.	Control.	Increase due to +nitrogen.	Per cent. increase.
Plot 4. (Cocksfoot : indigenous) ..	11,619	7,553	4,066	54
Plot 3. (Cocksfoot : commercial) ..	10,738	8,296	2,442	30
Plot 2. (Mixture)	12,992	11,867	1,125	10
Plot 1. (Wild white clover)	10,730	8,767	1,963	22
Average	11,520	9,120	2,400	26

It is noticed that the fertilizer has a much more pronounced effect on those plots which were low in clover content (Plots 3 and 4) than on the two plots which were relatively high in clover content (Plots 1 and 2). Indigenous cocksfoot, which had the lowest clover content of all the plots, showed a benefit to the extent of over 4,000 lb. in grass production through the application of the nitro-chalk, and this corresponds to a 54 per cent. increase, whilst the commercial cocksfoot plot, which comes next in the amount of clover present, showed a benefit of 2,442 lb., or a 30 per cent. increase. If the two plots rich in clover are considered, it is seen that of these two plots the one with the higher clover content benefited more from the application of the nitrogenous fertilizer. This on the face of it would appear to contradict the trend of the evidence as a whole, but on referring to Tables VI and X it will be found that whereas the

fertilizer hardly affected the growth of clover on the plot sown with wild white clover only (Plot 1), it has checked it to a very marked extent on the mixture plot (Plot 2). Thus the application of the nitrogenous fertilizer on the mixture

TABLE XII.—*Showing the amount of wild white clover expressed as a percentage of the total herbage (grass, clover and weeds) produced that was eaten by the sheep.*

	1929		1930		1931		Average.	
	Nitrogen.	Control.	Nitrogen.	Control.	Nitrogen.	Control	Nitrogen.	Control.
Cocksfoot : indigenous	Trace.	Trace.	0.7	14.2	3.1	9.3	1.7	9.0
Cocksfoot : commercial	Trace	Trace	7.1	16.3	11.8	13.6	7.5	10.7
Mixture	22.9	36.6	13.7	37.5	4.3	5.3	11.1	19.1
Wild white clover	69.0	81.0	31.4	37.8	7.4	12.5	28.2	34.7

plot (Plot 2) has to a very real extent defeated its own ends in that it has considerably reduced the amount of clover, and thus a large proportion of the manure has to be used, and to that extent wasted, in order to compensate for the suppressed clover.

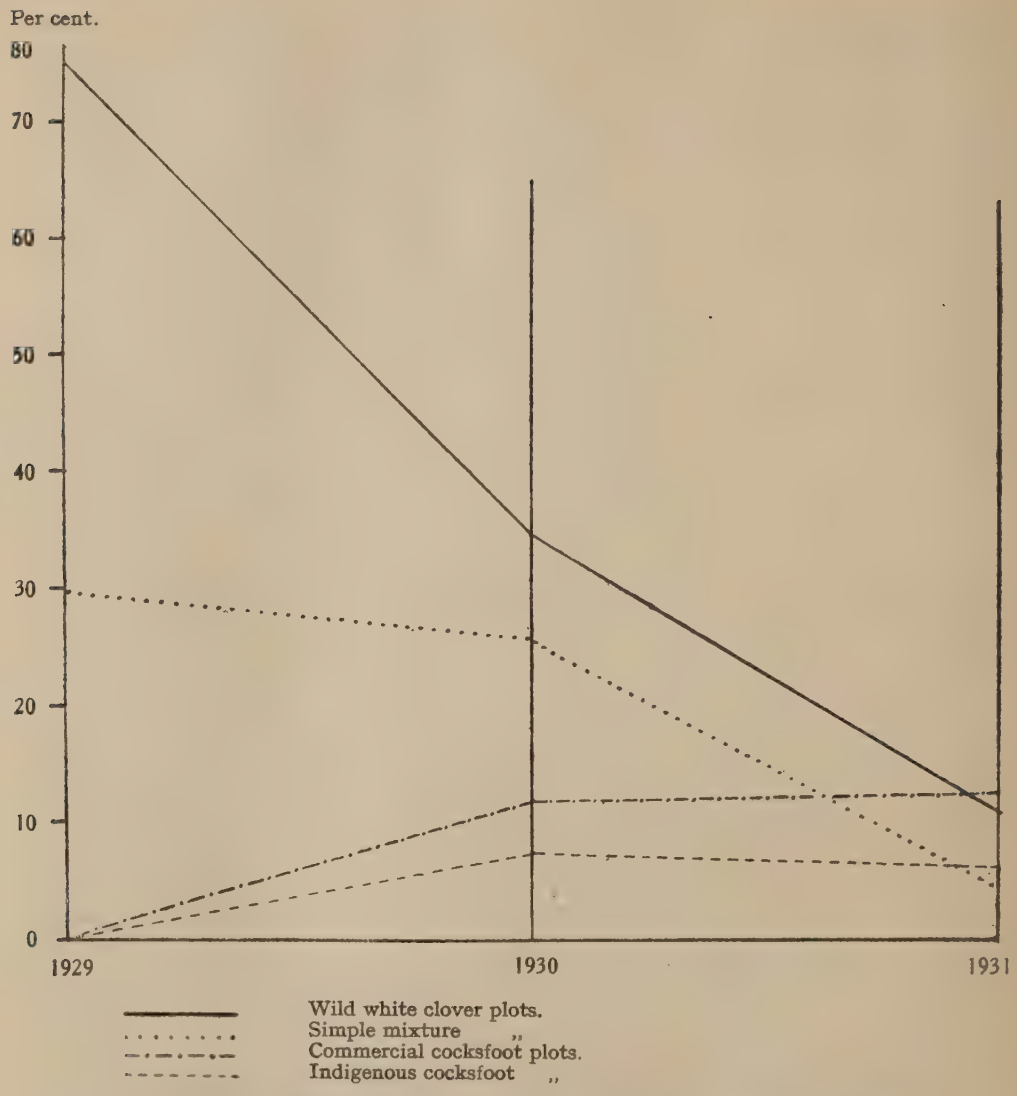
THE VARIATION IN THE CLOVER CONTENT OF THE PLOTS FROM YEAR TO YEAR.

The data presented in Table XII show the percentage of wild white clover in the herbage produced on the plots and eaten by the sheep. This varies greatly from plot to plot in one year and from year to year on the same plot. Thus, for example, the percentage of clover on the cocksfoot plots in 1929 was almost negligible, while on the wild white clover plot (Plot 1) it comprised 81 per cent. of the total herbage of the control area, and 69 per cent. on the area receiving dressings of nitro-chalk. On the other hand the percentage clover increased rapidly on the cocksfoot plots in 1930, and remained fairly stable in 1931, while it decreased rapidly on the wild white clover plot in 1930 and 1931. These changes are rendered the more apparent on reference to Text-figs. 2 and 3.

These data suggest that 1931 was an unfavourable year for the growth of white clover—far less favourable than 1930 although both were wet years. It would seem that the degree of intensity of grazing adopted (three weeks rest period) was decidedly favourable to the spread of wild white clover, and there is little doubt that if it had been possible to continue the experiment for a number of years the tendency would have been for the white clover content of all the plots to have become very similar—save that the content of the nitrogen plots would have remained lower than that of the no-nitrogen plots.

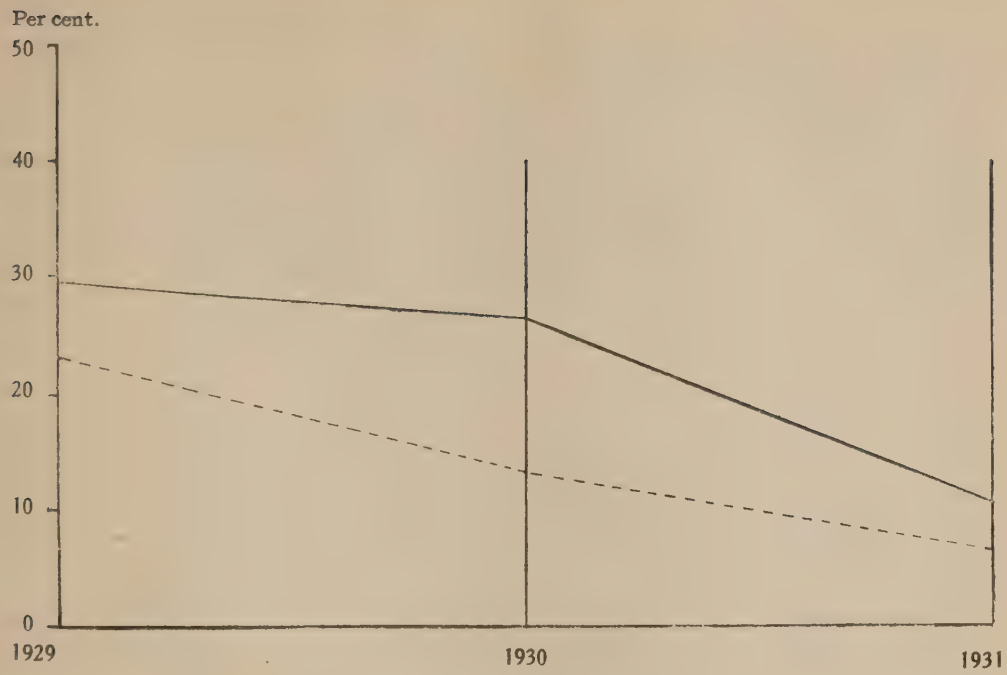
COMPARISON BETWEEN THE INDIGENOUS AND COMMERCIAL COCKSFOOT.

A comparison of the herbage produced by the commercial and indigenous cocksfoot plots (see Table XIII) shows that whereas the total herbage produced was slightly higher in the commercial plot, the yield of cocksfoot itself was 28 per cent. higher in the indigenous plot, while the yield of unsown species on the latter



Text-fig. 2. Graph showing the percentage productivity of wild white clover on each of the four plots (average of with- and without-nitrogen areas) for three harvest years respectively.

plot was very appreciably less than on the former. Furthermore, the yield of cocksfoot leaf was 38 per cent. higher in the indigenous plot, whilst the yield of stem was 26 per cent. less than that produced on the commercial plot. This, of course, amounts to saying that though the commercial plot produced more total herbage, the indigenous plot produced far more cocksfoot leaf.

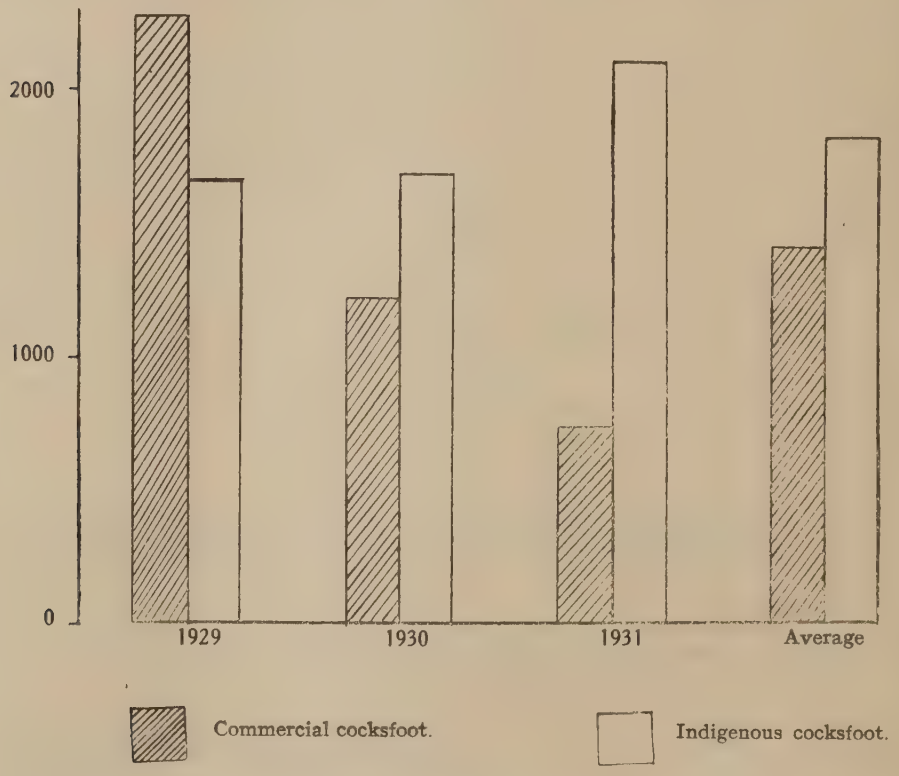


Text-fig. 3. **Graph showing the percentage of wild white clover respectively on the with- and without-nitrogen areas (average of the four plots) for each of the three harvest years.**

TABLE XIII.—*Showing the average yield per annum of the commercial and indigenous cocksfoot plots, expressed as lb. per acre.*

	Commercial cocksfoot.	Indigenous cocksfoot.	Indigenous expressed as per cent. of commercial.
Total herbage	3,484	3,377	97
Yield of unsown species	2,044	1,539	75
Yield of cocksfoot	1,440	1,838	128
Yield of cocksfoot leaf	1,200	1,661	138
„ „ „ stem	240	177	74
Per cent. of herbage as cocksfoot	41.3	54.4	—
Per cent. of cocksfoot as leaf	83.3	90.3	—

Table XIV shows the yields of the two cocksfoot plots for each year of the experiment. The most striking point is that whereas the yield of cocksfoot on the commercial plot decreases rapidly from year to year, that of the indigenous plot has increased. This is well seen on reference to Text-figs. 4 and 5. Reference to Table XIV, in the last two columns of which the cocksfoot yield is given as a percentage of the total herbage produced on the plots from year to year, reveals the fact that whereas commercial cocksfoot constituted 86 per cent. of the herbage in the first year, it deteriorated rapidly and formed only 14 per cent. of the herbage in the third grazing year. The indigenous cocksfoot on the other hand contributed 82 per cent. and 42 per cent. respectively for the corresponding periods.



Text-fig. 4. **Graph showing the yield of cocksfoot as such on the commercial and indigenous plots respectively for each of the three years—expressed as lb. of dry grass per acre.**

Text-fig. 5. Graph showing the percentage contribution of cocksfoot as such to the total herbage respectively on the indigenous and commercial plots.

TABLE XIV.—*To compare the yield of commercial and indigenous cocksfoot during each year of the experiment.*

Year	Yield of cocksfoot in lb. per acre.		Cocksfoot expressed as a percentage of total yield of herbage.	
	Commercial cocksfoot.	Indigenous cocksfoot.	Commercial cocksfoot.	Indigenous cocksfoot.
1929	2,250	1,690	86	82
1930	1,285	1,687	49	57
1931	734	2,111	14	42
Average	1,423	1,830	41	51

These data show that the ordinary commercial cocksfoot is far more productive than the indigenous strain in the first harvest year, but that it is not nearly so persistent under grazing conditions, and, compared to the indigenous, shows to very poor advantage in respect of yield in the third harvest year.

Other comparisons of the swards produced on the commercial and indigenous plots have been previously referred to, and may be conveniently summarized as under :—

(a) The white clover was more prolific on the commercial plot (see Table X), especially on the areas which had not received the nitrogenous fertilizer. This is not surprising in view of the fact that the cocksfoot had thinned out far more on the commercial than on the indigenous plot and consequently a better opportunity had been afforded for encroachment by other species. The native and volunteering wild white clover has made full use of this.

(b) The indigenous cocksfoot responded far more than the commercial cocksfoot to the application of nitro-chalk (see Table XI). The fertilizer increased the yield of the commercial strain by 30 per cent. and of the indigenous by over 50 per cent.

LIVE WEIGHT INCREASE OF THE SHEEP.

The botanical and yield data that have been discussed show how difficult it is to obtain accurate live weight data in respect of particular species and strains. The influence of the grazing animal on each plot is rapidly to upset the floristic balance of the plot. Thus it has been shown that it is impossible to maintain a wild white clover plot free from grasses, and it is equally impossible to maintain a pure grass plot free from volunteering wild white clover. Despite these obvious limitations, the experiment has given some very suggestive evidence as to the behaviour of the sheep in relation to the various rations offered to them. It will be convenient to discuss the data from various points of view. Details as to live weight increase in lb. per acre for the various plots for the three years are set out in Appendix Table III. It will be noted that the grazing seasons of 1930 and 1931 are divided into two parts, *a* and *b*, corresponding with the rearranging of the sheep in the grazing season. The main points brought out by the figures presented in the table will be dealt with under appropriate headings.

Seasonal Variation.

There is a considerable variation in live weight increase from period to period. Thus in 1930 the average increase in weight from all the plots is 356 lb. per acre up to July 12th and only 104 lb. from July 12th to the end of the grazing season, whilst in 1931 the plots average 258 lb. up to July 1st and 200 lb. from July 1st to October 16th. This variation is further shown in Table XV, where the increase is calculated as the daily live weight increase per acre. It is thus made evident that the first period in both years is far more productive than the latter half of the grazing season.

TABLE XV.—*Showing the live weight increase of sheep expressed as lb. per acre per day. Average of all plots.*

Year.	First period. Ending in July.	Second period. Ending in October.
1930	4.86 lb. per acre per day.	0.97 lb. per acre per day.
1931.	4.16 „ „ „ „ „	1.85 „ „ „ „ „

COMPARISON BETWEEN THE SEVERAL PLOTS.

There is a marked difference in the live weight increase on different plots. This point is well shown by reference to Table XVI. Although the number of sheep per plot is small in any one year, yet it is significant that all the plots with one exception take the same positions for each year. This exception is found in 1930 when the indigenous cocksfoot takes third position and commercial cocksfoot is last in the list. It is clearly shown in this table that the mixture (Plot 2) consisting of rye-grass, rough-stalked meadow grass and wild white clover gives very decidedly the best results with an average gain of 542 lb. live weight increase per acre per year. Wild white clover (Plot 1) comes second with 462 lb. per acre—80 lb. less than the mixture. Commercial cocksfoot (Plot 3) comes third with 356 lb. increase—106 lb. less than the wild white clover plot, and indigenous cocksfoot (Plot 4) on an average is last with 282 lb. or 74 lb. less than the commercial cocksfoot.

Furthermore, when the two plots sown with wild white clover (the wild white clover and the mixture plots) are averaged and also the two plots in which no wild white clover was sown (cocksfoot plots, Plots 3 and 4) it is seen that the former have given a far greater increase in live weight than the latter; on the average the with-clover plots giving a gain of 183 lb. per acre per annum in excess of the two cocksfoot plots. It is, therefore, evident that the contribution made by white clover to the herbage of a plot exercises a profound influence on the nutritive properties of such herbage. As a consequence of this, the live weight increase data for the commercial and indigenous cocksfoot plots, for example, in no wise represent the performance of the two strains of cocksfoot as such, since a much greater amount of white clover associated itself voluntarily with the commercial strain. Because of this clover factor different strains and different species of grasses can only be compared on the basis of the live weight increase for which they may be responsible by introducing them into contrasting simple mixtures all containing white clover. A large experiment involving a great number of plots and 48 pairs of tethered sheep has been set up this year to test the difference in feeding value between indigenous cocksfoot and indigenous perennial rye-grass on this, the simple mixture, basis.

TABLE XVI.—*Showing the live weight increases of sheep on the different plots, expressed in lb. per acre per annum.*

	1929	1930	1931	Total for three years.	Average per annum.
Plot 2. Mixture.	413	626	587	1,626	542
Plot 1. Wild white clover	358	537	490	1,385	462
Plot 3. Commercial cocksfoot	316	285	467	1,068	356
Plot 4. Indigenous cocksfoot ..	205	356	284	845	282
Average of mixture and wild white clover	386	582	539	1,507	502
Average of commercial and indigenous cocksfoot.	261	321	376	958	319
Difference	125	261	163	549	183

THE INFLUENCE OF NITRO-CHALK.

The effect of the nitrogenous manure on the live weight increase is shown for the several plots in Table XVII. When the control areas of all the plots are grouped together on the one hand, and the areas receiving nitrogen on the other, it is found that on an average the nitrogen areas have yielded 53 lb. (or nearly ½ cwt.) per annum more live weight increase than the control area. This increase, however, was not distributed uniformly over all the years, the best increase being obtained in 1929 with 107 lb. increase per acre, while in 1930 the live weight increase was actually depressed by the application of the manure. During 1929 there was a prolonged period of drought with the result that growth was slow, thus the sheep made full use of any further herbage which could be induced by nitrogenous manuring, hence the marked increase in live weight resulting from such manuring in 1929. In 1930 and 1931, however, the weather conditions were such as to be very favourable for growth, and each plot, the areas alike with- and without-nitrogen, produced ample food for its pair of sheep. The increased bulk produced by the application of the nitrogenous manure could not be made full use of; indeed it was sometimes harmful in that the growth on some occasions and on some plots was so rapid that the pasture produced tall, rank vegetation in three weeks and the herbage became unpalatable. This was markedly so in May and June, 1930, on the cocksfoot plots

TABLE XVII.—*Showing the effect of the nitrogenous fertilizer on the live weight increase of sheep. Expressed as lb. per acre per year.*

		1929	1930	1931	Average.
Average of all plots	Control	270	461	422	384
	+ Nitrogen	377	442	493	437
Increase due to nitrogen.		107	−19	71	53
Average of Plots 1 and 2. ..	Control	330	580	544	485
	+ Nitrogen	441	585	532	519
Increase due to nitrogen ..		111	5	−12	35
Average of Plots 3 and 4 ..	Control	209	342	299	283
	+ Nitrogen.	312	299	452	354
Increase due to nitrogen ..		103	−43	153	71

receiving nitrogen, whereas the control plots which had much shorter herbage were grazed fairly bare at each grazing, yet the sheep "did better" on the relatively less productive plots. Had the plots been larger it would of course have been possible to introduce additional sheep on the nitrogen areas at these periods and thus to have converted the extra growth and so maintained the areas in question in a proper condition.

In 1929 and 1931 the nitrogenous fertilizer on the cocksfoot plots gave a much higher live weight increase. In the case of the mixture and wild white clover plots, both of which contained a high percentage of wild white clover, the position is somewhat different except in the first grazing year (1929) when the mixture con-

tained very little clover and a high proportion of Italian and perennial rye-grass, with the result that the nitrogenous manure was responsible for an increased yield and an increased live weight increase. The wild white clover plot, however, contained very little grass in 1929, and the yield of herbage and the increase in live weight were not affected by the application of the nitrogenous manure. In 1930 and 1931 both the mixture and wild white clover plots contained a high proportion of wild white clover, with the result that the nitrogenous manure had little effect. These results agree with the data set out in Tables VIII and IX, and they serve to throw considerable light on the question of nitrogenous manuring. It would appear legitimate to state in so far as the provision of grazing is concerned during the period late April to the end of October that

(a) Pasture with little or no clover benefits most by the application of nitrogenous manures;

(b) Pasture with wild white clover in fairly large amount will benefit to an appreciable extent if the herbage is kept fairly short, as was generally the case on the wild white clover plots. If, on the other hand, the herbage grows rapidly, it soon sets up a keen competition with the wild white clover, with the result that whatever increase is obtained by the use of a nitrogenous manure is lost through suppression of the highly nutritious clover by the quick-growing grasses. Such to a marked degree was the case on the mixture plot.

CARRYING CAPACITY OF THE PASTURES.

The number of grazing days did not vary a great deal from year to year in this experiment when the average of all the plots is taken into consideration, as is shown by the following figures :—

1929—2,246 sheep grazing days per acre.
1930—2,278 „ „ „ „ „
1931—2,093 „ „ „ „ „

The variation on certain individual plots, however, was very noticeable. The more striking examples are set out hereunder :—

		1929.	1930.	
Mixture	+Nitrogen.	2,928	2,283	sheep grazing days.
Commercial cocksfoot ..	+Nitrogen.	2,688	2,245	„ „ „
Commercial cocksfoot ..	Control.	1,840	2,189	„ „ „
Indigenous cocksfoot	Control.	1,392	2,217	„ „ „

The weather conditions during 1929 were entirely different from those obtaining in the following two years. The summer of 1929 was extremely dry and hot, whilst 1930 and 1931 were both very wet and conducive to abundance of growth, but they differed from one another in that 1931 was a considerably later season than 1930, hence the smaller number of grazing days in the latter year.

The four plots differed to a considerable extent in the number of sheep grazing days which they provided, and this difference is still more marked in the early part of the spring, as is shown by the following figures :—

		No. of grazing days per year per acre.	*No. of grazing days per acre prior to May 1st.*
Wild white clover	(Plot 1) ..	2,236	105
The Mixture	(Plot 2) ..	2,330	215
Commercial cocksfoot	(Plot 3) ..	2,168	142
Indigenous cocksfoot	(Plot 4) ..	2,088	108

The above figures bring out the very important fact that wild white clover as such, although itself of marked feeding value, does not contribute in any quantity to the herbage early in the year, and, consequently, is without avail in supplying grazing days until the season is appreciably advanced. The nutritive value of the clover is further emphasised by this very fact, for both the live weight increase and the carrying capacity of the white clover plot when judged by its performance throughout the grazing season were second only to those of the simple mixture. It is interesting to note that the simple mixture plot containing considerable amounts of perennial rye-grass was more effective in providing early spring grazing days than was even the relatively early commercial cocksfoot. Indigenous cocksfoot (Plot 4), which kept itself relatively free from volunteer wild white clover, gave the poorest performance in total number of grazing days and was about equal to the wild white clover pasture in regard to its early spring growth. The low early spring figures for indigenous cocksfoot, however, were due to its very slow growth in its first grazing year (1929), whereas in 1930 and 1931 it gave higher figures than the commercial cocksfoot for both spring keep and total number of grazing days per year. This is shown by the comparison made hereunder :—

	Number of grazing days per year.		*Spring grazing.*	
	Commercial cocksfoot.	*Indigenous cocksfoot.*	*Commercial cocksfoot.*	*Indigenous cocksfoot.*
1929	2,264	1,928	232	32
1930 and 1931	2,120	2,169	97	147

Another point brought out in this experiment is the effect of nitro-chalk on the carrying capacity of the pasture. The following figures show the effect on each individual plot expressed in sheep grazing days per annum :

	Control.	*+Nitrogen.*	*Increase due to nitrogen.*
Plot 1. Wild white clover	2,232	2,241	9
Plot 2. Mixture	2,201	2,458	257
Plot 3. Commercial cocksfoot	1,970	2,366	396
Plot 4. Indigenous cocksfoot	1,830	2,347	517
Plot 2. { 1st year 1929	2,176	2,928	752
Plot 2. { 2nd and 3rd years 1930 and 1931 ..	2,214	2,224	10
Average of clover plots	2,216	2,350	134
Average of non-clover plots	1,900	2,356	456

It is to be particularly noticed that the nitrogenous fertilizer has hardly affected the carrying capacity of the wild white clover pasture (Plot 1). The mixture (Plot 2), however, has considerably increased its carrying capacity under the influence of the manure, but it is highly significant that this increase is nearly all due to its effect in the first year before the wild white clover had fully established itself and is hardly noticeable in the second and third years. The two cocksfoot plots, however, show a decided increase in the number of grazing days for all years where the nitro-chalk has been applied, and this increase is more prominent in the indigenous than in the commercial plot. On averaging the plots sown with clover (Plots 1 and 2) it is found that the application of the nitrogenous manure gave 134 days increase in the number of sheep grazing days, and this is mainly due to its effect on the mixture in 1929 before the clover formed a high percentage of the sward, while if we average the plots in which no clover was sown (Plots 3 and 4)

we find that they gave an increase of 456 sheep days. This increase was most noticeable during the early spring, and also during the drought period of 1929.

The following figures show the average number of sheep grazing days per acre obtained from each plot prior to May 1st for the three years :—

		Control.	*+Nitrogen.*	*Increase due to nitrogen.*
Wild white clover	(Plot 1)	102	108	6
The Mixture	(Plot 2)	170	259	89
Commercial cocksfoot	(Plot 3)	93	192	99
Indigenous cocksfoot	(Plot 4)	44	173	129
	Average	102	183	81
Mixture plot (Plot 2).	1929	176	416	240
,,	1930 and 1931 ..	167	180	13
Average of the plots with white clover (Plots 1 and 2)		136	183	47
Average of the two cocksfoot plots (Plots 3 and 4)		68	182	114

It is seen that taking into account all the plots for the total period of the experiment the nitrogenous manure gave 81 sheep grazing days more than the control area, that is to say, enough growth to keep 3 sheep for 21 days on an acre. Plot 1, however, gave little or no increase, and similarly the mixture gave very little, except in its first year, when the increased yield on the manured area as compared with the yield on the unmanured area was sufficient to carry 8 sheep for 30 days. The increased yield on the manured area of commercial cocksfoot and indigenous cocksfoot as compared with the yield on the unmanured area was sufficient to carry 3 sheep for a period of 33 days and 43 days respectively.

Again, on grouping the plots it is found that the nitrogenous manure had an altogether greater effect in producing early growth on the swards with little or no white clover than on the swards containing a high percentage of clover.

With regard to the drought of 1929 it is of considerable interest to observe that the white clover plot (both the manured and unmanured areas) provided a sufficiency of herbage to carry its normal quota of sheep in good health and condition right through the period. In the case of the other three pastures (namely, the mixture and the two strains of cocksfoot) all the areas receiving the nitrogenous manure were able to maintain their stock throughout. The unmanured mixture plot failed to maintain any sheep for a period of three weeks and the unmanured areas of both strains of cocksfoot were unable to maintain their stock for two periods of three weeks each during the droughty months. This evidence stands in support of two maxims of very considerable practical importance, namely, that a nitrogenous fertilizer does help to tide over a period of drought and that swards well endowed with white clover are peculiarly valuable in periods of drought.

THE GRAZING VALUE OF A PIECE OF NEGLECTED SWARD.

In 1931 a piece of land adjoining the plots immediately under discussion which had been seeded in 1928 with a mixture containing subterranean clover* was grazed along with the experiment with which we are primarily concerned. This pasture had reverted very quickly and was mainly composed of bent and Yorkshire fog, together with a fair proportion of cocksfoot and a very small amount of wild white clover. In 1930 the pasture had been fenced for periodic grazings, but owing to the limited number of sheep available during parts of the summer it was

*The mixture was as follows :—Italian rye-grass, 20 lb. ; perennial rye-grass (New Zealand) 14 lb. ; cocksfoot (indigenous), 10 lb. ; crested dogstail, 4 lb. ; rough-stalked meadow grass 4 lb. ; wild white clover, 2 lb. ; subterranean clover, 10 lb. ; rape, 8 lb.

never properly grazed with the result that a large amount of decaying and dry herbage was left at the base of the plants. The whole in 1931 provided a very inferior herbage for the sheep.

The area of the plot was half an acre and 4 pairs of tethered sheep were rotated over it to make the stocking comparable to the main experiment.

The grazing was begun on April 23rd and terminated on August 31st at which date the sheep had begun to lose weight and were manifestly in poor condition. The total increase in weight on this area was 140 lb., which corresponds to 280 lb. per acre. This in comparison with the results obtained from the simple mixture (see Appendix Table III) in the main experiment, is seen to be very poor, and furthermore, despite this increase in weight, the sheep lost rather than gained in condition; they maintained a certain measure of growth and nothing more.

A critical comparison of the sward developed upon this area in comparison with that given by the simple mixture would suggest the following reasons for the poor performance of the " out-run " area.

In the main the herbage offering to the sheep was of a dried character and consisted of an undue proportion of stemmy growth. The amount of clover in the herbage was at all times slight, while the herbage itself consisted predominantly of bent, which was never maintained in a close growing, palatable and nutritious condition.

SUMMARY AND DISCUSSION.

The evidence discussed in this paper, although preliminary and tentative, would seem to be highly suggestive in a number of practical directions. In the first place, it is rendered evident that it is exceedingly difficult to conduct an experiment of this sort, for the simple reason that it is impossible to maintain a single species sward in a state of purity for any very appreciable period of time. Thus, for example, the comparison which it was desired to make between indigenous and commercial cocksfoot was vitiated by the second year, because volunteer wild white clover largely took the place of the commercial strain, as the latter thinned out under the influence of the grazing animal.

In the second place, the fact that even in the first year, when both the commercial and indigenous strains of cocksfoot were providing by far the greatest bulk of herbage on their plots, the simple mixture plot gave very considerably the greater live weight increase is significant. This result would seem definitely to imply that a mixture of white clover and perennial rye-grass is of much greater feeding value than a diet consisting almost solely of cocksfoot. The results before us cannot be made the basis for comparing cocksfoot with rye-grass, because the rye-grass was associated with a large amount and the cocksfoot with a small amount of white clover. When, however, we take into account the fact that the simple mixture consisting of both grass and clover in good amount gave a better live weight increase (in the first year) than not only the cocksfoot plots, but also the white clover plot, which then consisted of much white clover and little grass, we have at least strong presumptive evidence suggesting that sheep do better on a diet consisting predominantly of two species (*e.g.* of perennial rye-grass and white clover) than predominantly of but one species (*e.g.* white clover alone or cocksfoot alone). As far as a comparison can be made between single species—and it is legitimate to compare wild white clover and cocksfoot in the first harvest year—it would appear that the advantage is with the clover. This is definitely so if we take the average of all the cocksfoot plots (indigenous and commercial with- and without-nitrogen) and compare it with the average of the

two white clover plots (with- and without-nitrogen). It is to be noted, however, as a matter of some importance that in this the first harvest year commercial cocksfoot aided by nitrogen has occasioned a slightly higher live weight increase than the clover plot. That such has proved to be the case, however, has been to a considerable extent due to the fact that the cocksfoot maintained its sheep for a longer period than did the clover.

Perhaps the most significant point brought out by these results has been the outstanding feeding value of a herbage consisting very largely of wild white clover. The results, however, also add emphasis to the fact that wild white clover does not as such provide abundant keep early in the spring.

Another interesting feature of these experiments has been a certain similarity in the action of wild white clover and of nitro-chalk. Both have served to safeguard the sward against the influences of a droughty period. Indeed, this definite evidence in relation to the action of nitro-chalk is of extreme practical importance, because farmers are sometimes recommended to withhold nitrogenous manures in anticipation of or during such periods. Although wild white clover is not itself a vigorous early spring grower, the results of these experiments definitely suggest that the presence of wild white clover in generous amount, like the addition of a nitrogenous manure, tends to encourage early spring growth on the part of the grasses. Thus on the simple mixture plots during the second and third harvest years (when the fertility effect of wild white clover would have been definite and pronounced) the number of "sheep days" prior to the 1st May given by the with-nitrogen plots was only 27 (for the two years) more than those given by the without-nitrogen plots.

Taking the results as a whole there is no question but that the addition of nitro-chalk has both augmented the live weight increase per plot and added to the carrying capacity of the swards. The fact remains, however, that on both counts the benefit has been altogether greater on the predominantly grassy than on the highly clovery swards.

The fact that a poor and previously neglected sward has not maintained its sheep in a thriving condition or been responsible for a substantial live weight increase has been an interesting quantitative confirmation of practical experience.

The chief results from the trial may be summarized in detail as under :—

(1) The Influence of Wild White Clover.

If the plots sown with wild white clover (the simple mixture plot and the wild white clover plot) are compared with those in which wild white clover was not included (the cocksfoot plots), we can draw the following conclusions. The presence of white clover appears to decrease the amount of weeds and moss and to increase the yield of grass as such : this is a result which is fully in accord with unpublished data collected from a large series of simple mixture experiments which were laid down in 1925. It adds to the carrying capacity of, and augments the live weight increase from, the plots. The increase in live weight from the clover plots is more pronounced than the increase in herbage produced. This suggests that wild white clover is of high feeding value, and is confirmatory of results recently reported by Roberts (1931 ; 1932), and is in keeping with the chemical evidence put forward by Williams and Evans (1932).

(2) The Influence of the Nitrogenous Manure.

Moss and weeds were suppressed by the nitrogenous manure, wild white clover was also suppressed. *Poa annua* and a number of other species were hardly affected. Rough-stalked meadow grass was more than doubled in amount. The yield of

herbage was much increased. This, however, was most pronounced in the first harvest year, which was also a dry and warm year. Taking the results from all the plots for the three years, the grasses contributing to the plots were increased 26 per cent. by the application of nitro-chalk while the clovers were decreased by nearly 25 per cent. The suppression of wild white clover was greatest on the plots which contained large amounts of aggressive growing grasses which responded most freely to the nitrogen, namely, on the simple mixture plot and on the indigenous cocksfoot plot.

On the average of the four swards for the three years the areas receiving nitrogenous manure gave nearly ½ cwt. per acre more live weight increase than the areas without nitrogen.

(3) The Influence of Wild White Clover and of Nitro-Chalk Compared.

The nitrogenous manure increased the amount of herbage on the with-clover plots by 667 lb. per acre, and on the cocksfoot (non-clover) plots by 2,868 lb. per acre. These large differences are to be explained thus: on the mixture plot the grass growth was so abundant under nitrogen that the clover was decreased by 44 per cent.; on the other hand, the amount of wild white clover was practically negligible on the cocksfoot plots, while on the white clover plot there were no aggressive grasses like cocksfoot and perennial rye-grass, and consequently, the white clover suffered but little suppression under the influence of nitrogen. The effect of the nitrogen acting practically only on grass was all gain on the cocksfoot plots. On the wild white clover plot the amount of grass present was not sufficient in quantity nor of a character seriously to depress the clover, and on the balance there was a slight gain. On the mixture plot, on the other hand, the added nitrogen had to compensate in grass for a really serious decrease in clover before showing anything to its credit—and thus from the point of view of gross yield and of nutritive value the manured plot showed to relatively slight advantage. In the matter of live weight increase we have differences of the same general order. Thus on the cocksfoot plots the nitro-chalk (on the average of the duration of the experiment) has been responsible for a live weight increase per acre per annum of 71 lb., while on the mixture and white clover plots the increase under similar treatment has been 35 lb. Nitrogen on the cocksfoot plots has been responsible for 456 additional sheep grazing days and on the with-clover plots for only 134 additional days.

(4) Indigenous and Commercial Cocksfoot Compared.

The indigenous cocksfoot in this experiment, as in previous experiments, has proved itself to be altogether more persistent than the commercial. One result of this has been a far greater ingress of unsown species on the plot sown with the commercial strains.

The yield of commercial cocksfoot as such decreased rapidly from 2,250 lb. in the first year to 734 in the third year, while that of the indigenous cocksfoot increased from 1690 lb. in the first year to 2,111 in the third year. In the third year the contribution of cocksfoot to the total herbage was only 14 per cent. in the case of the commercial strain, while it was 42 per cent. in the case of the indigenous. The indigenous strain gave a much higher response to nitrogenous manure than did the commercial.

From the point of view of carrying capacity and of live weight increase the plot sown with the commercial strain has given the best results. As previously explained, however, subsequent to the first harvest year this has been due to the not inconsiderable volunteer appearance of wild white clover and other grasses which has more than compensated for the dwindling cocksfoot.

Further experiments are now in progress with a view to arriving at a just comparison between rye-grass and cocksfoot on the one hand, and between different strains of cocksfoot on the other.

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EXPLANATION OF PLATE III.

Photograph showing method of tethering sheep. Grazed area in foreground; ungrazed area in background.

PLATE III.

APPENDIX.

APPENDIX TABLE I.—*Showing the number of tillers of plants per square foot. (Average of February and December, 1931, analyses; 30 turfs 6 in. × 6 in. on both occasions.)*

Plot.	Manure	Perennial rye-grass.	Cocks-foot.	Rough stalked meadow grass.	*Poa annua*	White clover	Bent	Fog	Other grasses.	Weeds	Total tillers	Moss
Cocksfoot: indigenous	Control ..	—	384	244	136	84	132	112	10	12	1,114	14½
,,	+Nitrogen	—	392	568	80	32	84	152	8	6	1,322	7
Cocksfoot: commercial	Control ..	—	70	300	112	112	436	188	28	24	1,270	37½
,,	+Nitrogen	—	84	780	132	70	292	140	40	12	1,550	19½
Wild White Clover ..	Control ..	—	—	212	560	236	152	8	Trace	4	1,172	3½
,,	+Nitrogen	—	—	400	400	240	200	16	2	6	1,264	2½
Mixture	Control ..	672	—	268	48	140	68	32	16	4	1,248	9
,,	+Nitrogen	604	—	408	88	98	28	4	—	4	1,234	5½

APPENDIX TABLE IIA.—*Showing the pasture yields in* 1929 *in lb. per acre.*

	Manure	Total yield.	Yield of						Per cent.		
			Cocksfoot.	Cocksfoot leaf.	Cocksfoot stem.	Perennial ryegrass.	Wild white clover.	Other unsown species.	Of herbage as cocksfoot.	Of cocksfoot as leaf.	Of herbage as wild white clover.
Plot 1. :—											
Wild white clover	Control ..	2,776	—	—	—	—	2,240	536	—	—	81
„	+Nitrogen	3,328	—	—	—	—	2,312	1,016	—	—	69
Plot 2. :—											
Mixture ..	Control ..	2,814	—	—	—	1,743	1,089	42	—	—	37
„	+Nitrogen	3,420	—	—	—	2,540	780	100	—	—	23
Plot 3. :—											
Commercial cocksfoot ..	Control ..	2,326	2,085	1,688	397	—	Trace.	241	90	81	Trace.
	+Nitrogen	2,884	2,422	2,058	364	—	—	462	84	85	—
Plot 4. :—											
Indigenous cocksfoot ..	Control ..	1,331	1,040	925	115	—	—	291	79	89	—
	+Nitrogen	2,805	2,340	2,190	150	—	—	465	84	94	—

APPENDIX TABLE IIB.—*Showing the pasture yields in* 1930 *in lb. per acre.*

	Manure.	Total yield.	Yield of						Per cent.		
			Cocksfoot.	Cocksfoot leaf.	Cocksfoot stem.	Perennial ryegrass.	Wild white clover.	Other unsown species.	Of herbage as cocksfoot.	Of cocksfoot as leaf.	Of herbage as wild white clover.
Plot 1. :—											
Wild white clover ..	Control ..	4,141	—	—	—	—	1,581	2,560	—	—	37.8
,,	+Nitrogen.	4,481	—	—	—	—	1,404	3,077	—	—	31.4
Plot 2. :—											
Mixture.	Control ..	3,540	—	—	—	2,062	1,330	148	—	—	37.5
,,	+Nitrogen	3,823	—	—	—	3,158	526	139	—	—	13.7
Plot 3. :—											
Commercial cocksfoot	Control ..	2,065	1,052	922	110	—	328	685	51	87.0	16.3
,,	+Nitrogen	3,185	1,520	1,264	256	—	225	1440	50	83.0	7.1
Plot 4. :—											
Indigenous cocksfoot	Control	2,453	1,300	1,248	52	—	329	714	53	96.0	14.2
,,	+Nitrogen	3,512	2,073	2,012	61	—	28	1,391	59	97.5	0.7

APPENDIX TABLE IIc.—*Showing the pasture yields in* 1931 *in lb. per acre.*

	Manure.	Total yield.	Yield of						Per cent.		
			Cocksfoot.	Cocksfoot leaf.	Cocksfoot stem.	Perennial ryegrass.	Wild white clover.	Other unsown species.	Of herbage as cocksfoot.	Of cocksfoot as leaf.	Of herbage as wild white clover.
Plot 1. :—											
Wild white clover ..	Control ..	6,672	—	—	—	—	834	5,838	—	—	12.5
,,	+Nitrogen.	7,168	—	—	—	—	530	6,638	—	—	7.4
Plot 2. :—											
Mixture.	Control	8,312	—	—	—	7,872*	440	—	—	—	5.3
,,	+Nitrogen	7,368	—	—	—	7,055*	313	—	—	—	4.3
Plot 3. :—											
Commercial cocksfoot	Control	4,893	564	425	139	—	665	3,664	11.5	75.4	13.6
,,	+Nitrogen	5,544	904	758	146	—	650	3,990	16.3	83.8	11.8
Plot 4. :—											
Indigenous cocksfoot	Control. ..	4,641	2,135	1,724	411	—	433	2,073	45.9	80.7	9.3
,,	+Nitrogen	5,522	2,087	1.821	266	—	170	3,263	37.8	87.3	3.1

* Includes sown and unsown grasses.

APPENDIX TABLE III.—*Showing the live weight increase of sheep in lb. per acre.*

	Manure.	1929	1930		1931		Total.	Average.
			a	*b*	*a*	*b*		
Plot 1. Wild white clover	Control ..	352	462	20	285	209	1,328	443
"	+Nitrogen ..	364	448	145	274	211	1.442	481
Plot 2. Mixture	Control ..	308	452	224	336	259	1,579	526
"	+Nitrogen ..	518	412	164	338	242	1,674	558
Plot 3. Commercial cocksfoot	Control ..	248	274	16	164	227	929	310
"	+Nitrogen ..	384	196	84	293	250	1,207	402
Plot 4. Indigenous cocksfoot	Control ..	170	336	59	106	101	772	257
"	+Nitrogen ..	240	268	50	261	99	918	306

a—first grazing period (ended July 12th, 1930, and July 1st, 1931).
b—second grazing period.

APPENDIX TABLE IVA.—*Showing the number of grazing sheep days per year per acre on each plot.*

Year.	Plot 1.		Plot 2.		Plot 3.		Plot 4.	
	Control.	+ Nitrogen.	Control.	+ Nitrogen.	Control.	+ Nitrogen.	Control.	+ Nitrogen.
1929	2,240	2,240	2,176	2,928	1,840	2,688	1,392	2,464
1930	2,292	2,319	2,264	2,283	2,189	2,245	2,217	2,414
1931	2,164	2,164	2,164	2,164	1,880	2,164	1,880	2,164
Average	2,232	2,241	2,201	2,458	1,970	2,366	1,830	2,347

APPENDIX TABLE IVB.—*Showing the number of grazing days prior to May 1st of each year.*

Year.	Plot 1.		Plot 2.		Plot 3.		Plot 4.	
	Control.	+Nitrogen.	Control.	+Nitrogen.	Control.	+Nitrogen.	Control.	+Nitrogen.
1929	—	—	176	416	176	288	—	64
1930	178	197	206	233	103	159	131	328
1931	128	128	128	128	—	128	—	128
Average	102	108	170	259	93	192	44	173

PLANT LIST.

GRAMINEAE

Sweet vernal	*Anthoxanthum odoratum* L.
Meadow foxtail	*Alopecurus pratensis* L.
Timothy	*Phleum pratense* L.
Bent	*Agrostis* species
Red top	*Agrostis palustris* Huds.
Brown top	*Agrostis tenuis* Sibth.
Yorkshire fog	*Holcus lanatus* L.
Golden oat	*Avena flavescens* L.
Tall oat	*Arrhenatherum avenaceum* Beauv.
Crested dogstail	*Cynosurus cristatus* L.
Cocksfoot	*Dactylis glomerata* L.
Rough-stalked meadow grass	*Poa trivialis* L.
Annual meadow grass	*Poa annua* L.
Meadow fescue	*Festuca elatior* L. sub-sp. *pratensis* Hackel
Tall fescue	*Festuca elatior* L. sub-sp. *arundinacea* Hackel.
Fine-leaved red fescue	*Festuca rubra* L.
Field brome	*Bromus arvensis* L.
Perennial rye-grass	*Lolium perenne* L.
Italian rye-grass	*Lolium italicum* Braun.

LEGUMINOSAE

Red clover	*Trifolium pratense* L.
Subterranean clover	*Trifolium subterraneum* L.
White clover	*Trifolium repens* L.

MISCELLANEOUS SPECIES

Mouse-ear chickweed	*Cerastium vulgatum* L.
Daisy	*Bellis perennis* L.
Chicory	*Cichorium Intybus* L.
Cat's-ear	*Hypochaeris radicata* L.
Moss	*Musci* species.

The Library of the Welsh Plant Breeding Station and Imperial Bureau of Plant Genetics : Herbage Plants is anxious to complete its sets of certain periodicals, and would therefore appreciate information leading to the acquisition of the parts or volumes enumerated below :—

American Naturalist (The), Vol. LIV. No. 635. Nov.-Dec., 1920.
Vol. LVI. No. 643. Mar.-April, 1922.

Botanical Magazine. Tokyo, Vol. 37. No. 435. 1923.

Farming in South Africa, Vol. II. Nos. 17, 20, 22 (Aug., 1927, Nov., 1927 ; Jan., 1928 respectively).

Genetics, Vol. I. No. 2. 1916.

Genetica, Vol. I. 1919.

Journal of Agricultural Research, Vol. VI. No. 16. July, 1916. Vol. VII. All parts after No. 12, including index to Vol. VII. 1916

Journal of the American Society of Agronomy, Vol. 8. No. 4. pp. 209-272. 1916.

Journal of the Department of Agriculture, Ireland, Vol. I. 1900.

Journal of Genetics, Vol. IV. No. 1. 1914.

Mededeelingen v.d. Landbouwhoogeschool, Wageningen.
Vol. 24. Nos. 1 and 2. 1922.
Vol. 29. 1925.

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Nature, Nos. 2853 (1924), 2907 (1925), and 2979 (1926).

New Zealand Journal of Science and Technology, Vol. I. No. 1. 1918.

Pflanzenbau, Vol. I. 1924-25.

Zellstimulationsforschungen, Vol. I. No. 2. 1925.

Zemědělský Archiv. Vol. XVIII. Nos. 7-8, 1927.
Vol. XIX. Nos. 3-4, 5-6, 1928.
Vol. XX. Nos. 3-4, 1929.

The following publications have been issued from the Station and may be obtained post free from the Secretary, Welsh Plant Breeding Station, Agricultural Buildings, Alexandra Road, Aberystwyth, at the prices stated :—

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